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USSR Report

PHYSICS AND MATHEMATICS

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method with an intrinsic vibrating frequency of 130 kHz, is analyzed for temperatures ranging from 1.7 to 300 K. The measurements were made on four polycrystalline specimens of $Tb_2Ti_2O_7$ from different batches, and also on an isomorphic diamagnetic $Tb_2Ti_2O_7$ compound. The modulus of elasticity is found to drop significantly in $Tb_2Ti_2O_7$ in the low temperature region. Analysis shows that this drop is due to electron-deformation interaction and the specifics of the structure of the lower-energy levels of the Tb^{3+} ion in the crystal field of the $Tb_2Ti_2O_7$ lattice. Figures 2, references 3: 2 Russian, 1 Western.

6900/12379
CSO: 1862/251

LIFETIME OF CHARGE CARRIERS IN DOPED AND VERY WEAKLY COMPENSATED SEMICONDUCTORS

Moscow PISMA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian Vol 43, No 10, 25 May 86 (manuscript received 4 Apr 86) pp 480-482

[Article by L.A. Vorozhtsova, Ye.M. Gershenzon, Yu.A. Gurvich, F.M. Ismagilova, A.P. Mel'nikov, and R.I. Rabinovich (deceased), State Pedagogical Institute imeni V.I. Lenin]

[Abstract] A study of doped and very weakly compensated silicon was made, for the purpose of determining the lifetime of charge carriers excited from neutral centers. Silicon with a concentration of neutral centers $N = 10^{13}$-10^{17} cm^{-3} was doped with boron to levels of acceptor concentration $N_A = (0.03\text{-}5.8)\cdot 10^{16}$ cm^{-3} and compensated to levels of $K = 10^{-5}$-10^{-3} only. Charge carriers were excited with radiation in the $\lambda = 8$-12 μm wave band at rates of $W = 10^{-2}$-10^{2} s^{-1}. Their concentration c and mobility u were measured over the 4.2-20 K temperature range by the photoelectric Hall-effect method, whereupon their lifetime was calculated as $\tau = c/WN$. Both electron lifetime and hole lifetime were determined in this way. The same procedure was followed for silicon doped similarly with phosphorus or gallium. The results reveal an anomalously short lifetime, four orders of magnitude shorter than with the concentration of attracting centers $N^{\pm} = KN$. This is attributed to indirect capture of charge carries by attracting centers, to which they either jump or drift from neutral centers capturing them first. The lifetime of charge carriers in such a semiconductor was found to anomalously depend on the concentration of neutral centers or even to be entirely determined by it. The authors thank V.N. Abakumov, V.I. Perel', and I.N. Yasiyevich for discussion of the results and helpful comments. Figures 2; tables 1; references 4: all Russian.

2415/12379
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UDC 621.378.34

DEVELOPMENT OF HIGH-POWER WIDEBAND LASER SYSTEMS BASED ON DYE SOLUTIONS

Minsk ZHURNAL PRIKLADNOY SPEKTROSKOPII in Russian Vol 44, No 2, Feb 86 (manuscript received 5 Nov 84) pp 214-219

[Article by S.A. Batishchye, V.I. Gurlenya, N.A. Malevich, V.A. Mostovnikov, P.I. Myashalov, and G.A. Tatur]

[Abstract] This study examines the basic factors that must be taken into account in developing high-power nanosecond-pulse pumped dye lasers suitable for use in wideband laser systems with high-efficiency nonlinear frequency converters. A system is described in which the master laser and dye amplifiers are excited by radiation from a ruby laser system consisting of a monopulse laser, preamplifier, and two amplifiers. Radiated power of approximately 1 kW is achieved at the wavelength of hydrogen, which is sufficient for high-temperature plasma research. Figures 2, references 18: 11 Russian, 7 Western.

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UDC 621.375.82

SENSITIVITY OF INTRACAVITY SPECTROSCOPY IN NANOSECOND DYE LASERS

Minsk ZHURNAL PRIKLADNOY SPEKTROSKOPII in Russian Vol 44, No 5, May 86 (manuscript received 26 Dec 84) pp 757-761

[Article by V.S. Burakov, V.A. Malashonok, S.V. Nechayev, R.A. Puko, and S.I. Shedenkov]

[Abstract] The method of intracavity spectroscopy and factors affecting its sensitivity are examined, three main factors being multiple passage of light through the laser resonator during an emission period, threshold effects, and competitive interaction of laser modes. Threshold effects and competitive interaction play a particularly important role in ultrashort-pulse (nanosecond) lasers, inasmuch as intracavity absorption saturates within 150-200 ns after the emission threshold has been reached and the sensitivity decreases when the pump power exceeds that threshold. Other factors are the magnitude of

selective losses and the width of absorption line contours in various emission modes of a multimode laser, particularly critical being the situation where the spectrum of selective losses is much narrower than the amplification line contour. All these effects were studied using a laser on VRO dye in dioxane solution (382-413 nm) for spectroscopy of iron and molybdenum vapors in an electrothermal atomizer at a temperature of 3100 K, using a laser on rhodamine 6Zh dye in ethanol solution for spectroscopy of the Eu^{3+} ion in an aqueous solution of $Eu(NO_3)_3.H_2O$ within the range of $^5D_0-^7F_0$ transition (579 nm) and comparing the absorption spectrum with the emission spectrum, and using a laser on oxazine 17 dye in ethanol solution for spectroscopy of the Ho^{3+} ion in a $KY(WO_4)_2:Ho^{3+}$ crystal within the range of $^5F_5-^5J_8$ transition (648 nm). In each case were measured the maximum depth of dip in the laser emission spectrum as well as its dependence on the produce kl (k- absorption coefficient, l- length of absorbing layer) and on the ratio γ/Γ (γ -width of absorption line contour, Γ - width of laser emission spectrum). The results indicate that the relative depth of the spectral dip decreases with increasing spectral density of laser emission power and with increasing γ/Γ ratio, but increases with increasing kl product. The sensitivity gain of intracavity measurement over extracavity measurement, calculated as the ratio of relative spectral dips in each case, is found to decrease with increasing γ/Γ ratio as well as with increasing kl product. The maximum sensitivity gain of 2-3 is determined by the number of times N one photon passes through the laser resonator, this number depending on the reflection coefficient R of the exit mirror: $N = 1/(1- R)$. Figures 3; references 15: 7 Russian, 8 Western (1 in Russian translation).

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UDC 535.3

EMISSION OF SECOND-HARMONIC LASER RADIATION DURING NONCOLLINEAR INTERACTION OF LIGHT WAVES DIFFRACTED BY ULTRASOUND

Minsk ZHURNAL PRIKLADNOY SPEKTROSKOPII in Russian Vol 44, No 5, May 86 (manuscript received 1 Aug 83) pp 761-769

[Article by N.S. Kazak, Ye.M. Miklavskaya, and M.I. Sergiyenko]

[Abstract] Second-harmonic generation by interaction of a light wave and an ultrasonic wave in a uniaxial nonlinear crystal such as a $LiNbO_3$ crystal is analyzed, including the reaction of both diffracted wave and second-harmonic wave on the incident radiation so as to take into account depletion of pumping energy by diffraction. The analysis is based on the vector wave equation describing Bragg diffraction of a strong light wave by ultrasound. For a uniaxial noncentrisymmetric crystal with an ultrsonic wave traveling along the optical axis or z-axis and a light wave traveling in a principal plane or xy-plane at a small Bragg angle to the x-axis, this equation reduces to a system of three coupled equations for the amplitudes and amplitude gradients of the three interacting waves. Smallness of the angle between diffracted waves and

slowness of the variation of amplitudes in the direction of synchronism make the variation of the electric field negligible in the z-direction and in the y-direction, respectively, so that the problem reduces to a one-dimensional one and namely with respect to the x-axis only. Analytical solution of these equations for the amplitude of the second-harmonic wave and numerical solution for interaction with phase mismatch reveal that diffraction contributes to frequency doubling, along with frequency conversion, and that this contribution increases with increasing acoustic power while it also depends on the phase mismatch as well as on the ratio of characteristic conversion length to characteristic diffraction length in the crystal without an acoustic field present. Figures 4; tables 1; references 6: all Western (1 in Russian translation).

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UDC 535.37

EFFECT OF RELAXATION PROCESSES ON KINETICS AND POLARIZATION DEGREE OF FLUORESCENCE OF RHODAMINE 6Zh IN GLYCERIN SOLUTION

Minsk ZHURNAL PRIKLADNOY SPEKTROSKOPII in Russian Vol 44, No 5, May 86 (manuscript received 29 Jan 86) pp 769-776

[Article by L.V. Levshin, I.A. Struganova, and B.N. Toleutayev]

[Abstract] Fluorescence of organic substances with nonuniform widening of the spectrum is analyzed, its mechanism depending on the kind of substance. Rhodamine 6Zh was selected for an experimental study of fluorescence kinetics and polarization, in glycerin solution and in ethanol solution with equal concentrations of 10^{-6} mole/dm^3. The fluorescence extinction time was measured with a subnanosecond spectrofluorometer and a plain pulse fluorometer. The spectrofluorometer included a picosecond YAG:Nd laser with acoustooptical Q-switching, mode locking, and frequency conversion to second-harmonic radiation at λ = 532 nm wavelength synchronously pumping a picosecond dye laser tunable over the 555-585 nm wavelength band, the spectral lines of both lasers being $\Delta\lambda$ = 0.1 nm wide and their pulse durations being τ~0.1 ns. The time resolution and the time error of the fluorometer were $\tau_{min} \sim 0.5$ ns and $\Delta\tau$~0.05 ns respectively. The fluorescence polarization was measured with a spectrofluorometer consisting of a quasicontinuous LTI-701 laser as excitation source (emission wavelength λ = 532 nm, spectral width $\Delta\lambda$ = 0.1 nm. pulse duration τ~300 ns, pulse repetition rate ν = 25 kHz, polarization vertical with not more than 0.1% deviation) and a DFS-12 monochromator followed by a Frank-Ritter polarizing prism and then an FEU-107 photomultiplier feeding signals through a d.c. amplifier to a digital voltmeter. With rhodamine 6Zh in glycerin solution there was noted not only a bathochromic shift of the fluorescence spectrum at room temperature, as the excitation wavelength was varied over the absorption band from the short-wave edge to the long-wave edge, but also a temperature dependence of the wavelength λ_{max} corresponding to

maximum glow intensity based on measurements made over the -60-(+60)°C temperature range. With rhodamine 6Zh in ethanol solution there was noted no dependence of the fluorescence spectrum on the excitation wavelength at room temperature, indicating a much weaker nonuniform widening of electron levels in molecules. In glycerin solution the nonuniform widening of electron levels is dynamic orientational, as in dipole substances, resulting in a shift of λ_{max} and evidently caused by relaxation processes in excited molecules. The dependence of the fluorescence extinction time and polarization degree in glycerin solution on the emission wavelength at various excitation wavelengths reveals a "dip" of extinction time and a corresponding "peak" of polarization degree. Both shift together toward the red region of the spectrum as the excitation wavelength is increased, but neither shift nor change in magnitude as the excitation intensity is varied over a wide range covering two orders of magnitude. No such "dip" and "peak" appear with rhodamine 6Zh in ethanol solution. They are attributable to buildup of a nonequilibrium distribution of fluorescence centers at frequencies of 0-0 transition in a solvent-dye dipole system such as rhodamine 6Zh in glycerin solution and its subsequent transformation into an equilibrium distribution within the relaxation time.
The authors thank B.D. Ryzhikov for discussion of the results.
Figures 4; references 16: 14 Russian, 2 Western.

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DISPERSION OF REFRACTIVE INDEX OF SEMICONDUCTORS AT EDGE OF FUNDAMENTAL ABSORPTION BAND

Minsk ZHURNAL PRIKLADNOY SPEKTROSKOPII in Russian Vol 44, No 5, May 86 (manuscript received 24 Dec 84) pp 838-845

[Article by T.A. Kudykina and M.P. Lisitsa]

[Abstract] Dispersion equations describing the frequency dependence of the refractive index n( ) of semiconductor lasers at the edge of their fundamental absorption band are derived theoretically and matched with experimental data. The theory is based on the relation between complex dielectric permittivity and refractive index as a function of frequency each, in the approximation of random phases, including both ground state and excited state of electrons in the Kramers-Heisenberg relation for polarizability. Both real and imaginary parts of dielectric permittivity are evaluated, assuming a valence band fully occupied by electrons and an empty conduction band ($kT<<E_g$), for the case of direct dipole-allowed transitions and for the case of direct dipole-forbidden transitions with the contribution of indirect transitions included wherever it is significant. The dispersion equations for these two cases agree fairly well with approximate descriptions of experimental data pertaining to semiconductors

with exciton transitions (CdS, CdSe, InP, GaAs, ZnTe) and without exciton states (PbTe, InSb, InAs) respectively. Figures 3; tables 2; references 9: 3 Russian, 6 Western (1 in Russian translation).

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STUDY OF INITIAL STAGE OF OPTICAL BREAKDOWN NEAR SOLID SURFACE BY SPECTRAL METHODS

Minsk ZHURNAL PRIKLADNOY SPEKTROSKOPII in Russian Vol 44, No 5, May 86 (manuscript received 18 Jan 85) pp 845-849

[Article by V.V. Brunov, A.A. Gorbunov, and V.I. Konov]

[Abstract] Laser-induced optical breakdown near a solid target surface in air and under a vacuum of 1-2 Pa was studied, of particular concern being the spectral composition of radiation from the plasma during the initial stage of such a breakdown: the first microsecond. The necessary high time resolution for this study was attained by using an "Agat" electron-optical camera, its time resolution of 5 ns being adequate when compared with a longer than 10 ns radiative relaxation time of free atoms. Optical breakdown was induced by a high-intensity pulse from a transverse-excitation atmospheric-pressure CO_2-laser, of 0.25 μs duration at the base with a 3.5 μs long "tail" containing two thirds of the total pulse energy. Such a pulse of laser radiation, after attenuation by a set of polyethylene filters, was focused normally incident on various targets (graphite, copper, K-8 quartz glass) within an area of 4 mm^2. The spectrum of plasma radiation could be measured with a resolution of 2 nm and the time delay from beginning of the laser pulse to triggering of the camera could be determined with an error not larger than ±25 ns. Measurements covered the 480-630 nm range of the spectrum. Those made with the targets in vacuum revealed no presence of residual air in graphite and an early recovery of the pure metal upon removal of contaminating and eroding oxides. Measurements made with the targets in air revealed a threshold laser radiation intensity, $1.4 \cdot 10^7$ W/cm^2 for breakdown of K-8 glass containing 10.4% Na_2O, a dependence of the flash time on the laser radiation intensity, and breakaway of the plasma from the solid surface with subsequent shock-wave propagation of the discharge bucking the laser at a laser radiation intensity above the critical $4 \cdot 10^7$ W/cm^2 for this glass. The authors thank D.S. Lukovnikov for assistance in setting up the tests. Figures 2; references 11: 8 Russian, 3 Western.

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UDC 535.317.1

POSITION OF IMAGE OF VOLUME HOLOGRAM RECONSTRUCTED BY SMALL-APERTURE BEAM

Minsk ZHURNAL PRIKLADNOY SPEKTROSKOPII in Russian Vol 44, No 5, May 86 (manuscript received 9 Apr 84) pp 863-867

[Article by V.G. Bondarenko]

[Abstract] Forming a holographic image is analyzed as a problem of geometrical optics, such an image being formed as a result of reflection of the reconstructing light beam by semiopaque mirror layers in the hologram emulsion layer. Assuming a small aperture of the hologram and a usual thickness of its emulsion layer, one can consider the curvatures and other parameters of the reflecting surfaces to be invariable. The reflecting layers for a hologram of a point object are surfaces of hyperboloid of revolution and a homocentric reconstructing light beam reflected by an anamorphotic mirror with meridional focus and sagittal focus generally becomes astigmatic. The distance of the image from the plane of minimum cross-section of such a reconstructing light beam is calculated accordingly from the equation of a hyperboloid surface in the appropriate system of coordinates, with the aid of the Young formulas for the focal lengths and the Euler formulas for the curvatures of such a mirror. Figures 2; references 5: 3 Russian, 2 Western.

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EXPERIMENTAL STUDY OF CO_2-LASER AMPLIFIER WITH MIRROR BASED ON DEGENERATE FOUR-WAVE INTERACTION

Moscow KVANTOVAYA ELEKTRONIKA in Russian Vol 13, No 5, May 86 (manuscript received 31 Jul 84, after completion 18 Apr 85) pp 900-905

[Article by D.A. Goryachkin, V.P. Kalinin, I.M. Kozlovskaya, I.A. Komin, and N.A. Romanov]

[Abstract] An experimental study of a CO_2-laser amplifier with a mirror based on four-wave interaction was made, for the purpose of determining the energy-space characteristics of its output radiation. The equipment included a master laser oscillator (volume of active medium 3x3x100 cm^3) with a dispersive resonator, generating radiation tunable over 10P-branch lines in pulses of 5 J energy and 10 μs duration at base level, a preamplifier (volume of active medium 10x10x100 cm^3), and a telescopic main amplifier consisting of an array of photoionization chambers in a two-pass configuration. The radiation from the laser oscillator was split by a ZnSe wedge into three beams, two of which

with a pulse energy of 1.5 J each pumped the mirror from opposite directions and then passed through a cell containing SF_6 (interaction space 13 mm long) from different directions. The third beam generated a signal, a part of it being first widened by a 3:1 telescope to the size of the output beam and then reflected by a BaF_2 wedge before passing through the active media of the amplifier stages. A high reflection coefficient at the mirror was attained by ensuring mutual coherence of the signal beam and the two pump beams, namely by equalization of the corresponding optical paths within appropriate accuracy. This ensured coherence also when the path difference was equal to double the resonator length (L= 3 m) or to any other even multiple thereof. The reflected power increased and the reflection coefficient decreased with increasing signal power, also with increasing input power. The performance of this amplifier at high energy levels of 25-30 J indicates the feasibility of generating a laser beam with 85x85 mm^2 cross-section and only $4.4 \cdot 10^{-4}$ rad divergence by effective phase conjugation during degenerate four-wave interaction, random nonuniformities in the signal beam being partly compensated. A still higher amplifier gain is evidently attainable with a multipass amplifier configuration. The authors thank V.Ye. Sherstobitov for attentiveness and helpful discussions. Figures 6; references 10: 8 Russian, 2 Western.

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USE OF COMPOSITE RESONATORS FOR WIDENING RANGE OF CONTINUOUS FREQUENCY TUNING OF GAS LASERS

Moscow KVANTOVAYA ELEKTRONIKA in Russian Vol 13, No 5, May 86 (manuscript received 25 Feb 85) pp 932-936

[Article by V.N. Bel'tyugov, A.A. Kuznetsov, V.N. Ochkin, N.N. Sobolev, Yu.V. Troitskiy, and Yu.B. Udalov, Institute of Physics imeni P.N. Lebedev, USSR Academy of Sciences, Moscow]

[Abstract] A composite open resonator with a diffraction grating, and with a reflective diffraction interferometer instead of a Fabry-Perot etalon, is considered for continuous frequency tuning of gas lasers over a wide range $\Delta\nu > c/2L$ (c - velocity of light, L - length of resonator) after mode extraction. The possibility is analyzed theoretically, taking into account the frequency dependence of selective and nonselective losses in the resonator as well as the dependence of the tuning sharpness on the mode frequency separation. The feasibility is demonstrated on a CO_2-laser with the bandwidth of a resonator stage $\Delta\nu_L$ = 200 MHz, c/2L = 200 MHz, c/2d = 4.3 GHz (d - interferometer base), and $2g_0L^* = 0.5$-0.8 (g_0 - gain at center of stage, L^* - length of active medium). Typical pressure of the active medium is 20-40 mm Hg and the tuning sharpness index for diffractional selectors is typically F_R = 10-15. Experiments were performed using a trielectrode quartz tube 5 mm in diameter with a 40 cm long discharge gap and a CO_2:N:He:Xe = 1:0.5:4:0.25 active mixture

under a pressure of 36 mm Hg. The resonator had an optical length of 75 cm. Longitudinal modes at the P(18) line of the 00°1-10°0 transition could be tuned over a 300 ± 15 MHz range. Figures 4; references 7: 4 Russian, 3 Western.

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STABILIZING COMPOSITION OF GAS MEDIUM OF PERIODIC-PULSE CO_2-LASER WITH USE OF HOPCALITE

Moscow KVANTOVAYA ELEKTRONIKA in Russian Vol 13, No 5, May 86 (manuscript received 21 Mar 85) pp 989-992

[Article by V.Yu. Baranov, G.F. Drokov, V.A. Kuzmenko, V.S. Mezhevov, and V.V. Pogul'skaya, Institute of Atomic Energy imeni M.V. Kurchatov]

[Abstract] While palladium has excellent mechanical properties, it is not sufficiently active as catalyst at low temperature and requires preheating of the laser gas to approximately 200°C. Hopcalite is an excellent catalyst at low temperatures already, but it has a low mechanical strength and tends to pulverize. While it has already been successfully used for stabilizing the composition of the gas medium of a monopulse CO_2-laser, its use as stabilizer for a periodic-pulse CO_2-laser is still problematic. An experimental study of this problem was made, mainly for the purpose of determining the performance characteristics of this catalyst and finding out why its activity decreases with time. For the experiment was used a CO_2-laser with ultraviolet preionization, its active medium having a volume of 660 dm^3 and its discharge gap having a volume of 0.3 dm^3. The electrodes, both 50 cm long, were separated by a 25 mm wide gap and connected to a 0.1 μF capacitor bank. The gas composition was monitored with an MSKh-5 time-of-flight mass-spectrometer and an LKhM-8M chromatograph, the latter including a column with polysorber for separating CO_2 from O_2, N_2, CO and a column with molecular sieves for separating O_2, N_2, CO. The rate of CO_2 decomposition having been found to remain almost constant in time, the object of measurements was to determine its dependence on the laser pulse repetition rate, on the laser gas pressure, and on the input energy. No leveling was reached, because the discharge contracted before that. In a CO_2:N_2:He = 2:1:5 mixture it was possible to have more than 30% CO_2 decompose under a pressure of 0.3 atm, at a laser pulse repetition rate of 400 Hz. The relative rate of CO_2 decomposition was found to generally increase with decreasing pressure, with 3 kg hopcalite in a bypass vessel. With a gas flow rate of 6 dm^3/s under a pressure of 0.5 atm and at a discharge voltage of 25 kV, the CO_2 decomposition stabilized at the 6% level and the laser power stabilized at 80% of its initial level for a period of 8 h of continuous operation. The catalyst lasted for 30 h within one month, after having been stored for one year. A separate test with hopcalite in a glass vessel under a vacuum of 10 μm Hg and with thermostatic control over the 0-50°C

temperature range, with the laser pulse repetition rate varied over the 50-500 Hz range, has revealed that the principal cause of decreasing catalyst activity is obstruction of its active centers by nonvolatile compounds adsorbed from the vessel walls. The activity of this catalyst was fully restored by heating for 3-4 h at 150°C in vacuum or at 250°C in air. Figures 2; references 11: 4 Russian, 7 Western.

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HIGH-POWER ION LASER WITH BROAD FUNCTIONAL CAPABILITIES

Moscow KVANTOVAYA ELEKTRONIKA in Russian Vol 13, No 5, May 86 (manuscript received 26 Mar 85) pp 1004-1009

[Article by A.A. Apolonskiy, V.I. Donin, and T.T. Timofeyev, Institute of Automation and Electrometry, Siberian Department, USSR Academy of Sciences, Novosibirsk]

[Abstract] A reliable Ar^+-laser has been built capable of generating 40-50 W of visible radiation or 10 W of ultraviolet radiation with the discharge current at saturation level. The discharge tube was designed for optimum gas pressure and discharge current. Its basic dimensions are accordingly a diameter of 7 mm and a length of 70 cm, which also lower the voltage requirement for sustaining a discharge to 300 V so that power can be drawn from a 380/220 V network through a 3-phase bridge rectifier without transformers. The tube is made of mechanically strong metal, not solid but consisting of 13 mm long segments, with alumina coating. The main problem, namely eliminating the pressure drop along the active discharge space especially in the paracathodic region, has been solved by cutting 18 small "electrophoresis" holes along the discharge channel and additional transverse slots near the cathode. The power-current characteristics of this MIL-05 laser and the voltage-current characteristics of the discharge were measured during continuous-wave operation at visible 4p-4s transitions in the Ar-II ion, with the pressure varied over the 0.28-0.4 mm Hg range. A maximum efficiency of 0.1% was reached somewhat below the maximum power of 50 W, at the 514.5 nm wavelength, with a current of almost 200 A and the voltage-current characteristics had no negative-slope segments. At ultraviolet 4p-4s transitions in the Ar-III ion a maximum power of 10 W was reached 351.1 nm and 365.8 nm wavelengths, with a current of 250 A and with internal mirrors having transmission coefficients T_1 = 1% (plane mirror) or T_2 = 0.2% (concave mirror). The mirrors had been produced by electron-beam evaporation. A resonator of "large effective length" is most expediently used for angular tuning (of the TEM_{00}-mode, for example) with a solid concave mirror and a solid convex mirror, a Littrow prism with a transmission coefficient of 3-7% acting as a plane mirror at the exit for wavelength (line) tuning. A V-form resonator with three mirrors is also used for mode locking, with a $LiCHO_2.H_2O$ nonlinear crystal in a

collinear configuration for oo-e interaction serving as second-harmonic generator for measurement and control of the laser pulse duration (crystal cut at 38° angle for locking modes at the 514.5 nm wavelength). This MIL-05 laser can be used for pumping a dye laser, most practical then being a dye solution in ethylene glycol. The authors thank A.F Belozerov and V.A. Seleznev for stimulating discussion during first stage of this study, and Ye.N. Smirnov for assistance in building the mode locking device. Figures 4; references 9: 5 Russian, 1 East German, 3 Western.

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KINETICS OF BREAKDOWN OF METAL VAPOR BY LASER BEAM IN ATMOSPHERE OF ATOMIC GAS

Moscow FIZIKA PLAZMY in Russian Vol 12, No 6, Jun 86 (manuscript received 14 May 85, after correction 14 Aug 85) pp 714-720

[Article by V.S. Vorobyev, S.V. Maksimenko, and A.L. Khomkin, Institute of High Temperatures, USSR Academy of Sciences]

[Abstract] The problem of a laser beam passing through an atomic gas with vapor of a metal as impurity is analyzed, considering that, owing to the low ionization potential of such a vapor and the high initial degree of gas ionization, the breakdown radiation intensity is much lower for such a vapor than for a cold gas. The equations of electron diffusion and heat conduction for the gradients of electron concentration and temperature are formulated so as to describe the vapor breakdown and ionization kinetics with the attendant energy balance, first for an infinitely large vapor cloud and then for a vapor cloud of finite size with appropriate boundary conditioned and assuming central symmetry in each case. Into account are taken ambipolar diffusion, ionization and recombination processes, elastic collisions between electrons and gas atoms, and backbraking by gas atoms. The equations are solvable numerically means of a completely conservative difference scheme, an implicit Newton scheme being used for the equation of heat conduction. Calculations have been made for argon at a temperature $T = 0.175$ eV under a pressure of 1 atm, a tantalum vapor impurity in a Tl:Ar = $1.48 \cdot 10^{-5}$:1 ratio, and a laser beam with a radius $R = 0.06$ cm. They have yielded the dependence of the breakdown radiation intensity on the temperature of the metal surface and also the radial profile of electron temperature. Following breakdown at a radiation intensity of 8.2 MW/cm^2, the electron concentration increases jumpwise till it becomes equal to the metal concentration while the electron temperature continues to increase linearly with increasing radiation intensity. The breakdown radiation intensity depends only slightly on the radius of the laser beam. Analogous calculations have been made for helium and xenon with tantalum vapor near the surface of solid metal. The theoretical results agree closely with available

experimental data. The authors thank A.M. Dykhna, A.P. Napartovich, and A.N. Starostin for discussion and valuable critical comments. Figures 4; references 7: all Russian.

2415/12379
CSO: 1862/226

FEASIBILITY OF USING $Ln_{1-x}Sr_x CoO_3$(Ln:La,Nd) OXIDES FOR CATHODES OF CO_2 WAVEGUIDE LASERS

Leningrad PISMA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 12, No 10, 26 May 86 (manuscript received 26 Feb 86) pp 622-627

[Article by D.N. Zybin, N.I. Lipatov, P.P. Pashinin, A.N. Petrov, A.M. Prokhorov, and V.Yu. Yurov]

[Abstract] The performance and life of CO_2 waveguide lasers depend largely on the cathode material, which should be characterized by high electrical conductivity and emission capacity in a weakly ionized cold plasma, formability into intricate shapes, and electromechanical compatibility with cermets in structural components. It must also have a high friability threshold and its powder must be chemically passive so as not to form volatile compounds with any material of the laser hardware or with any molecular component of the discharge plasma. In addition, it must not oxidize so as not to shift the CO_2 dissociation equilibrium, a high donor capacity relative to oxygen being desirable on account of inevitable loss of oxygen through absorption by other laser hardware materials, and it must be able to efficiently reduce CO as well as nitrogen oxides so as to prevent loss of active CO_2 and N_2 while also protecting the plasma in the positive discharge column. Oxides of the $Ln_{1-x}M_xM^*O_3$ system (Ln = La,Nd,Pr, M = Sr,Ca,Ba, M^* = Mn,Co,Ni,Cu) are very promising in this respect, combining all the properties required of a cathode material and also being strongly catalytic for the $CO + 1/2O_2 \rightarrow CO_2$ reaction. A model experiment was performed with two such oxides, $La_{0.7}Sr_{0.3}CoO_3$ and $Nd_{0.7}Sr_{0.3}CoO_3$, the La:Sr=0.7:0.3 having been selected as the optimum one with regard to maximum electrical conductivity (up to $2 \cdot 10^3$ $ohm^{-1}cm^{-1}$), donor capacity, and catalytic capacity. The optimum temperature of orthocobaltite synthesis, ensuring monophasality of the compound is near 1150°C, synthesis being followed by sintering of the ceramic material in air at 1400°C. Their most important performance characteristic as cathode material, namely dependence of the normal current density j_n on the gas pressure p, was measured over the 10-150 mm Hg pressure range in pure helium and in CO_2:N_2:He = 1:1:8, 1:1:4 mixtures. The relation was found to be the classical one, $j_n = Kp^2$ with K = 13.1 for La-Sr orthocobaltite and K = 8.5 for Nd-Sr orthocobaltite over the 1-30 mA range of discharge current. The characteristic cathode warmup time to 200°C was found to be 1-2 min. The emission capacity of these two materials is approximately equal to that of stainless steel and tantalum carbide, being surpassed only by that of nickel. Figures 1; tables 1; references 7: 3 Russian, 4 Western.

2415/12379
CSO: 1862/223

NONLINEAR REFLECTION AND REFRACTION OF SUPERSHORT LIGHT PULSES BY SURFACE OF RESONANT MEDIA AND PHASE "MEMORY" EFFECTS

Moscow ZHURNAL EKSPERIMENTALNOY I TEORETICHESKOY FIZIKI in Russian Vol 90, No 6, June 86 (manuscript received 16 Jan 86 after revision) pp 1938-1951

[Article by R.A. Vlasov, O.N. Gadomskiy, I.V. Gadomskaya, and V.V. Samartsev, Institute of Physics, Belorussian SSR Academy of Sciences]

[Abstract] This study investigates regularities occurring when supershort laser pulses interact with the surface of a resonant medium and phase memory of the surface atoms occurs. Computation of the reflecting capacity of the surface is demonstrated by irradiating the surface using two pulses with the help of the scanned beam and traveling surface electromagnetic waves. The proposed procedure for calculating the surface optical properties can be extended to more complex cases employing three or more laser pulses. Figures 4, references 24: 18 Russian, 6 Western.

6900/12379
CSO: 1862/258

UDC: 621.373.826.038.825.2

PICOSECOND GARNET ERBIUM LASER (A-2.94MM) WITH ACTIVE MODE SYNCHRONIZATION

Moscow KVANTOVAYA ELECTRONIKA in Russian Vol 13, No 3, 1986 (manuscript received 15 Jan 85) pp 499-509

[Article by L.I. Andreyeva, K.L. Vodopyanov, S.A. Kaidalov, Yu.M. Kalinin, M.Ye. Karasev, L.A. Kulevskiy and A.V. Lukashev, Institute of General Physics, USSR Academy of Sciences, Moscow]

[Abstract] A report is presented on studies of the time and spectral characteristics of a picosecond YAG:Er laser with active mode locking and wave length 2.94 um. The use of electro-optical loss modulation in a system with partial polarizers yields stable generation with peak energy about 0.5 mJ. Impulses have a length of 77-106 ps, energy density 0.7 GW/cm^2. The time substructure of the pulses is explained by insufficient generation development time, meaning that initial noise bursts cannot be smoothed. The laser signal is very sensitive to tuning accuracy of the optical length of the resonator. A change in resonator length of about 0.1 mm influences the signal. Figures 7, references 17: 12 Russian, 5 Western.

6508/12379
CSO: 1862/194

UDC 533.6.011:621.373.826.038.823

THERMAL EFFECTS IN ABSORPTION OF CO_2 LASER RADIATION BY WATER VAPOR

Moscow KVANTOVAYA ELECTRONIKA in Russian Vol 13, No 3, 1986 (manuscript received 18 Dec 84) pp 551-558

[Article by V.A. Levin, A.A. Sorokin and A.M. Starik, Institute of Mechanics, Moscow State University imeni M.V. Lomonosov]

[Abstract] A study is made of the possibility of cooling water vapor by exposure to radiation at λ=10.6 μm and the mechanism explaining the effect is analyzed. Studies were performed for a medium with a composition close to that of air, containing H_2O, N_2 and O_2. A system of kinetic equations is presented for the oscillating energy exchange in the medium. The mechanism of cooling is similar to the mechanism analyzed earlier for absorbtion of resonant radiation in the P branch of an oscillating rotary band of diatomic molecules. An upper estimate for the maximum possible cooling effect is derived. The maximum cooling is achieved for radiation with ν_I=1066.037 cm^{-1}. The effect may occur when continuous radiation acts on a gas containing water vapor moving at supersonic velocities. Figures 3, references 23: 11 Russian, 12 Western.

6508/12379
CSO: 1862/194

UDC: 621.373.826.038.824

NEW IR FLUORESCENCE BANDS IN CONCENTRATED SOLUTIONS OF POLYMETHINE DYES AND PROSPECTS FOR CREATION OF EFFECTIVE LASERS

Moscow KVANTOVAYA ELECTRONIKA in Russian Vol 13, No 3, 1986 (manuscript received 26 Dec 84) pp 575-581

[Article by V.A. Babenko, M.A. Kudinova, V.I. Malyshev, Yu.L. Slominskiy, A.A. Sychev and A.I. Tolmachev, Institute of Physics imeni P.N. Lebedev, USSR Academy of Sciences, Moscow]

[Abstract] A study is made of the spectroscopic characteristics of solutions of two polymethine dyes with different concentrations in solution, photochemically stable and with good solubility. The dyes, number 4652-u and 4483-u, are dissolved in 1,2-dichloroethane and nitrobenzene. Absorbtion spectra are obtained using a scanning dual-beam spectrophotometer with fluorescence excited by a train of ultra short pulses from a neodymium laser at 1.055 μm, mean pulse length 3.5 ps. The formation of an additional fluorescence band with an increase in dye concentration in the solution is a specific peculiarity of the new compounds and is apparently related to the nature of their excitation. Two possible mechanisms for formation of the

additional band are suggested: optical excitation of stable exiplex formations in the dye molecules and redistribution relative to the number of excited molecules in favor of the lower stable energy levels due to a migration mechanism of transfer of excitation with an increase in concentration of molecules in the solution. Figures 10, references 13: 10 Russian, 3 Western.

6508/12379
CSO: 1862/194

UDC: 621.373.826.038.823

ELECTRON DENSITY WAVE AND PRODUCTION OF SUPER SHORT PULSES IN A HIGH PRESSURE CO_2 AMPLIFIER

Moscow KVANTOVAYA ELECTRONIKA in Russian Vol 13, No 3, 1986 (manuscript received 26 Dec 84) pp 582-588

[Article by V.T. Platonenko and V.D. Taranukhin, Moscow State University imeni M.V. Lomonosov]

[Abstract] A study is made of the influence of an electron density wave on an amplified pulse, and the possibility is discussed of using this effect to obtain super short light pulses. It was found that the combination of active and reactive mechanisms of shortening of the electron density wave may result in a significant decrease in the duration of nanosecond and picosecond pulses. References 7: 5 Russian, 2 Western.

6508/12379
CSO: 1862/194

UDC: 621.373.826.038.823

REFRACTION OF LASER RADIATION ON SELF-ACTION WAVES IN CO_2 LASERS

Moscow KVANTOVAYA ELECTRONIKA in Russian Vol 13, No 3, 1986 (manuscript received 2 Jan 85) pp 617-622

[Article by V.Ye. Semenov, S.V. Fedorov, and M.S. Yuryev]

[Abstract] This work, continuing a previous work, is dedicated to a numerical investigation of the influence of refraction of laser radiation on self-action waves (SAW) on the divergence of the radiation of an electron-ionization laser with a telescopic resonator. It is demonstrated that the thermal self-action is a significant factor in disrupting the optical quality of the medium and causes significant deterioration of divergence of the radiation under typical conditions. The method used allows rapid performance of calculations. In addition to the SAW arising at the boundary of a laser beam, small-scale

volumetric SAW also arise in a CO_2 las caused by mode intensity variations within the resonator. Cathode and anod waves are also important in their influence on optical quality. Figures 5, references 10: 8 Russian, 2 Western.

6508/12379
CSO: 1862/194

UDC: 621.373.826

SUPPRESSION OF BACK WAVE DURING PUMPING OF 4-WAVE WFR MIRROR WITH CO_2 LASER WITH UNSTABLE RESONATOR

Moscow KVANTOVAYA ELECTRONIKA in Russian Vol 13, No 3, 1986 (manuscript received 2 Jan 85) pp 623-629

[Article by D.A. Goryachkin, V.P. Kalinin, I.M. Kozlovskaya, I.A. Komin, N.A. Romanov and V.Ye. Sherstobitov]

[Abstract] A study is made of two systems for polarization suppression of back waves using only simple plate-type polarizers installed at the Brewster angle. In the first scheme, the initial laser radiation is linearly polarized at 45° with a Brewster plate in a branch of the unstable resonator. The two pumping beams of the mirror are formed by cutting off various sections of the leading edge of the output radiation. These beams have mutually perpendicular electric field vectors. Returning to the resonator, the two beams are directed in the same direction, orthogonal to the original direction. The back wave is suppressed by a polarizer located within the resonator. In the second scheme, the back wave is suppressed outside the resonator with a second plate installed at the Brewster angle and used in the mode of reflection from one of the faces. Results of model experiments on suppression of the back wave are presented. Figures 4; references 7: 5 Russian, 2 Western.

6508/12379
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UDC: 535.373.5

INERTIAL NONLINEAR PROCESSES IN LASER MEDIA AND THEIR INFLUENCE ON POWERFUL LASER BEAMS

Moscow IZVESTIYA AKADEMII NAUK SSSR: SERIYA FIZICHESKAYA in Russian Vol 50, No 4, Apr 86, pp 765-772

[Article by V.S. Zuev, K.S. Korolkov, O.Yu. Nosach and Ye.P. Orlov, Institute of Physics imeni P.N. Lebedev, USSR Academy of Sciences]

[Abstract] Processes which occur in the active media of powerful lasers and whose rates depend on the intensity of laser radiation influence the divergence of radiation of the lasers. Their influence on divergence results from nonlinear optical effects. As laser radiation acts on the speed of these processes, spatially heterogeneous variations in laser radiation intensity cause variations in the rate of change of enthalpy in the laser medium, leading in turn to gas dynamic displacement of the substance and changes in its optical properties. This type of forced scattering differs qualitatively from other types of forced scattering of light in the nature of interaction of the radiation with the medium. This type of enthalpy forced scattering excites powerful internal oscillations at comparatively low radiation intensities. The excitation of powerful ultrasonic and temperature waves can be explained only by considering chemical reactions occurring in the laser medium. The increments and times of development of instability under such conditions as a result of the inertial nonlinearity of the active medium are calculated. It is emphasized that processes of forced scattering of light are apparently inherent in practically all powerful lasers, since the rates of processes occurring in the active medium and the accompanying heat liberation are dependent on laser radiation intensity. The design of high power laser installations must therefore include analysis of the effects of nonlinear inertial self excitation of light resulting from forced scattering on the formation of laser radiation structure. Figures 2, references 32: 20 Russian, 12 Western.

6508/12379
CSO: 1862/201

UDC: 541.14:535.217

EXPLOSIVE ABSORPTION OF RADIATION

Moscow IZVESTIYA AKADEMII NAUK SSSR: SERIYA FIZICHESKAYA in Russian Vol 50, No 4, Apr 86, pp 715-723

[Article by A.N. Orayevskiy and I.Ye. Proshchenko, Institute of Physics imeni P.N. Lebedev, USSR Academy of Sciences]

[Abstract] Under certain conditions molecules can absorb laser IR radiation at the transitions between excited, initially practically unpopulated states. The mechanism of this phenomenon is analyzed. The threshold characteristics and basic features of explosive absorption are analyzed in a gas consisting of identical molecules irradiated by a laser field. Primary attention is given to the behavior of the absorbing substance in a fixed field of radiation. Explosive absorption of radiation has many potential practical applications as in the initiation of laser-chemical reactions and increasing the efficiency of lasers with external field pumping. The phenomenon can be used in spectroscopy for precise determination of the energies of excited states of particles. The effect can be used to crate absorption traps as well as devices for smoothing pulsations in radiation intensity. Figures 3, references 6: 4 Russian, 2 Western.

6508/12379
CSO: 1862/201

UDC: 621.373.826.038.823

ELECTRON DENSITY WAVE AND GENERATION OF VERY SHORT RADIATION PULSES IN THE IR BAND

[Article by V.G. Platonenko and V.D. Taranukhin, Moscow State University imeni M.V. Lomonosov]

[Abstract] A discussion is presented of one mechanism of sweeping the radiation frequency of laser pulses, the effectiveness of which increases with increasing wavelength. The mechanism consists of the interaction of the radiation with 3 carriers. The specific mechanisms of formation of electron density waves in a gas discharge plasma are discussed, including heating of the electrons by radiation and photoionization of electron-excited atoms in a field of intense radiation. Two shortening mechanisms associated with the electron density wave are noted: an active mechanism, related to absorption of energy by electrons, and a reactive mechanism, in which there are no energy losses. In semiconductors, electron density waves can also significantly shorten picosecond IR pulses. There are no limitations on the energy of the shortened

pulses, indicating the promise of the use of the electron density wave mechanism to shorten IR-band radiation pulses. References 8: 3 Russian, 5 Western.

6508/12379
CSO: 1862/201

UDC 533.95:533.9:537.84

SOLITARY VORTICES IN MAGNETOHYDRODYNAMICS

Riga MAGNITNAYA GIDRODINAMIKA in Russian No 4, Oct-Dec 85 (manuscript received 4 May 85) pp 73-79

[Article by S.I. Vaynshteyn]

[Abstract] Solutions to MHD problems are considered which describe configurations of solitary vortices. In the simplest nontrivial case of a plane configuration all fields are functions of only the two space coordinates x,y and independent of the third coordinate z. Configurations with rigid boundaries are obtained as steady-state solutions to the problem of ideal MHD with large plain and magnetic Reynolds numbers as well as large Lundquist number. Next are considered quasi-soliton solutions which describe configurations still bounded in space but with fields decaying fast at infinity rather than vanishing completely outside a certain region. Equilibrium configurations of the magnetic kind ($v = 0$, $H \neq 0$) are analyzed, for specificity, first axisymmetric ones and then more generally nonaxisymmetric ones. The conclusions of this analysis, applicable to plasmas in tokamaks, agree with experimental data on interaction of Rossby solitons. Figures 1; references 12: 6 Russian, 6 Western (1 in Russian translation).

[133-2415]
/12379

UDC 621.313.12:537.84

EFFECT OF GASDYNAMIC TURBULENCE ON INTEGRAL CHARACTERISTICS OF CONDUCTION-TYPE MHD-GENERATORS

Riga MAGNITNAYA GIDRODINAMIKA in Russian No 4, Oct-Dec 85 (manuscript received 28 Jan 85) pp 133-128

[Article by A.B. Vatazhin and Yu.S. Levitan]

[Abstract] The performance of conduction-type MHD generators with combustion products as the active medium is analyzed, taking into account fluctuations of

gasdynamic parameters in the MHD channel and in the combustion chamber but disregarding acoustic and other perturbations in both electric and magnetic fields as well as current fluctuations in the parelectrode regions and in the external electric circuit. Considering that fluctuations of gas velocity u', temperature T', and pressure p' can cause fluctuations of electrical conductivity σ', electric field intensity E', and current density j', thus also of Joule-effect heat generation q', all the correlation moments involving fluctuations of any electrical quantity and appearing in the equations of turbulent flow are included in the evaluation of the generator performances (integral) characteristics. Flow in the channel core of an MHD generator is treated in the approximation of a small magnetic Reynolds number and uniform distribution of gasdynamic fields ($\bar{u},\bar{T},\bar{p}$), disregarding fluctuations of the Hall coefficient. Calculations are based on averaging the equation of Ohm's law for orthogonally crossing electric and magnetic fields. Specific power P_y and specific heating q_v, both normalized to $\sigma u^{-2}B^2$ (B - magnetic induction), are obtained as functions of $\bar{E}_y/\bar{u}B$ with $v = w = 0$ and $\bar{E}_x/\bar{u}B = 0$ corresponding to a one-dimensional flow and a transverse electric field. These characteristics are calculated for a Faraday generator with solid electrodes, a Hall generator with solid electrodes, and a Faraday generator with diagonally conducting electrodes. For comparison, they are also calculated for the other extreme case of a conduction-type MHD generator with liquid-metal channel. The authors thank G.A. Lyubimov, V.I. Kovbasyuk, S.A. Medin, and other participants in the seminar at the Institute of High Temperatures (USSR Academy of Sciences) for fruitful discussion of the results. Figures 5; references 9: 7 Russian, 2 Western.

[133-2415]
/12379

NUCLEAR PHYSICS

LASER RESONANT PHOTOIONIZATION DETECTION OF TRACES OF ^{221}Fr RADIOACTIVE ISOTOPE IN SPECIMEN

Moscow ZHURNAL EKSPERIMENTALNOY I TEORETICHESKOY FIZIKI in Russian, Vol 43, No 2, Jun 86 (manuscript received 14 Apr 86) pp 570-572

[Article by S.V. Andreyev, V.S. Letokhov, and V.I. Mishin, Institute of Spectroscopy, USSR Academy of Sciences]

[Abstract] This study presents the results of spectral investigations and detection of Fr atoms with fluxes 10 times smaller than in previous work, which opens up fundamentally new possibilities in the atomic spectroscopy of radioactive elements, making it possible to work with activity smaller than 10^{-6} Curie under standard laboratory conditions. The findings indicate that there is an alternative spectroscopic procedure for elements that are not available in nature in quantities sufficient for optical investigations. Weak radioactive sources of these elements can be used in conjunction with ultrasensitive photoionization laser spectroscopy instead of using expensive accelerators to generate large amounts of such elements. Figures 3, references 7: 5 Russian, 2 Western.

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CSO: 1862/251

REMOTE NONLINEAR POLARIZATION SPECTROSCOPY OF RAMAN LIGHT SCATTERING

Moscow PISMA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian Vol 43, No 1, 10 Jan 86 (manuscript received 10 Nov 85) pp 43-46

[Article by A.F. Bunkin, A.S. Galumyan, and D.V. Mal'tsev, Institute of General Physics, USSR Academy of Sciences]

[Abstract] Nonlinear polarization spectroscopy of Raman light scattering in liquids was performed by a new method, namely by remote spectroscopy of the optical Kerr effect induced by resonance of Raman scattering with all information about the given medium contained in the variations of a strong coherent monochromatic wave propagating in exact opposition to the two incident pump waves. According to conventional procedures, changes in the elliptic polarization of the probing wave of frequency ω_1 were recorded during scanning of the frequency difference $\omega_1 - \omega_2$ between the two pump waves near the resonance of Raman scattering. Unlike in conventional nonlinear polarization spectroscopy, however, the two pump waves were allowed to intersect in the given medium at any angle rather than only at large angles, including parallel propagation, and stimulated Mandelshtam-Brillouin scattering of one of them was the source of the probing wave, with the recorded signal propagating at a 180° angle to the latter. This made remote measurements possible over distances limited only by the Mandelshtam-Brillouin threshold for one of the two pump waves. Experiments were performed with ethanol, acetone, distilled water, and sea water as scattering media. Second-harmonic radiation pulses at wavelengths $\lambda_1 = 532$ nm and $550 \leq \lambda_2 \leq 585$ nm, of $P_1 \simeq P_2 \simeq 2$ MW power and of 20 ns duration were generated by a single-frequency laser and a dye (rhodamine 6G) laser with a YAG:Nd^{3+} amplifier and a DSDA crystal each. These pump pulses were produced at a repetition rate of 10 Hz. Other equipment included a sharply polarizing calcite wedge, five rotatable plane mirrors, one focusing fixed spherical mirror, and a CAMAC crate with a photodiode-triggered register, a DVK-2 microcomputer, three FEU-79 photomultipliers, a graphic display, and an automatic recording instrument. The data point to a four-photon process as source of the recorded signal, which is confirmed by vanishing of the latter upon suppression of the second pump wave. This signal appears as a green spot placed before the diaphragm in front of the photomultiplier feeding into the CAMAC crate, its brightness decreasing with farther departure from the

resonance of Raman scattering. The data and their theoretical interpretation demonstrate the feasibility of remote Raman scattering spectroscopy by this nonlinear polarization method. Figures 3; references 5: 4 Russian, 1 Western.

[138-2415]
/12379

UDC: 535.434:551.593

DETERMINATION OF OPTICAL CONSTANTS OF SOLID PHASE OF AEROSOL IN THE AREA OF INTENSE INFRARED BANDS BASED ON REFLECTION OR TRANSMISSION SPECTRA

Dushanbe DOKLADY AKADEMII NAUK TADZHIKSKOY SSR in Russian Vol 28, No 7, Jul 85, pp 395-397

[Article by L.I. Alperovich, S. Latyfov, T.B. Mamchenko, Kh. Radzhabov, Tadzhik State University imeni V.I. Lenin]

[Abstract] A method for determining the optical constants of a solid aerosol based on measurement of the reflection spectra from the polished surface of a tablet obtained by pressing the powder is suggested and tested. Ammonium chloride and ammonium sulfate were used to test the method. Results are compared with data obtained earlier by the method of transmission through a finely dispersed layer precipitated on a substrate. It is concluded that for ammonium chloride the optical constants of the methods coincide with great accuracy. This work thus shows for the first time the possibility of high precision determination of the optical constants of dispersed particle materials. Figure 1, references 5: Russian.

6508/12379
CSO: 1862/117

UDC 621.373.8

WAVEFRONT CONJUGATION DURING FOUR-PHOTON PARAMETRIC INTERACTION UNDER CONDITIONS OF TWO-PHOTON RESONANCE OF WIDEBAND PUMPING FIELD

Minsk ZHURNAL PRIKLADNOY SPEKTROSKOPII in Russian Vol 44, No 2, Feb 86 (manuscript received 12 Jun 84) pp 325-328

[Article by A.A. Demin, I.A. Iskanderov, and S.V. Shklyarik]

[Abstract] Signal wavefront conjugation during four-wave parametric interaction is investigated in a two-level system using the approximation of assigned pumping fields and signal assuming inertial interaction and saturation of the two-photon transition and pumping spectrum width. The average intensity and spectrum of the conjugated wave is found in a pumping field with line width significantly exceeding the longitudinal and transverse relaxation rate. The wideband pumping efficiency is found to be inversely proportional to the square

root of the ratio of the spectral pumping width to the natural width of the two-photon transition. A spectroscopic system is described that makes it possible to measure the width of the uniform components of the two-photon transition and the composite matrix elements of transitions with the help of wideband pulse lasers. Figures 1, references 10: 8 Russian, 2 Western.

6900
CSO: 1862/146

UDC 517.958:537.812

REVERSE PROBLEMS OF COHERENT OPTICS: FOCUSING ONTO LINE

Moscow ZHURNAL VYCHISLITEL'NOY MATEMATIKI I MATEMATICHESKOY FIZIKI in Russian Vol 26, No 1, Jan 86 (manuscript received 7 May 84) pp 80-91

[Article by A.V. Goncharskiy and V.V. Stepanov, Moscow]

[Abstract] The problem of focusing coherent radiation onto a line, specifically onto a smooth plane curve without crunodes, is solved in the approximation of geometrical optics. The region G where the focusing element is located needs to be mapped accordingly from its plane $z = 0$ onto the focal plane $z = f$, which requires determining the eikonal $\varphi_2(u,v,z)$ pf the reflected wave when the eikonal $\varphi_1(u,v,z)$ of the incident radiation is given. The sought function $\varphi(u,v) = \varphi_2(u,v,0)$ is found in terms of images I_φ, the class of such images being limited to $I_\varphi G = L$ (L 1- focal curve) by the requirement of the problem. The class of curves L for which a smooth solution, namely a function $\varphi(u,v) \in C^2(G)$ twice continuously differentiable on region G, exists, is described by three theorems. The images are then synthesized with the aid of five lemmas leading to an existence theorem for a unique stationary family of straight lines and the point on region G through which they pass. A curve in the focal plane can thus be synthesized by mapping onto that plane straight-line segments across the region of the plane occupied by the focusing element. This is demonstrated based on a simple example of focusing a circular radiation spot with uniform intensity distribution onto a circular arc with uniform intensity distribution. The procedure is applicable to construction of programmable optical elements for focusing laser radiation onto arbitrary curves. Figures 1; references 6: all Russian.

123-2415/12379

UDC 535.3+535.375

STIMULATED SCATTERING OF LIGHT IN PHYSICS AND ENGINEERING

Moscow VYNUZHDENNOYE RASSEYANIYE SVETA in Russian 1985 (signed to press 10 Jul 85) Chapter 6, pp 136-175

[Article by M.M. Sushchinskiy]

[Abstract] Stimulated scattering of light, particularly Raman scattering, has found important applications in laser physics and laser engineering. One of them is frequency conversion, pumping radiation of some wavelength being focused onto an active medium which converts it by scattering into radiation with Stokes components of another wavelength. One known scheme for achieving this is use of long fiber optics as active medium; another one is amplification of the external signal by interaction of the pump pulses and the first Stokes component propagating either in the same direction with resulting saturation amplification and high conversion efficiency or in opposite directions with resulting lower efficiency but shorter Stokes pulses. An important factor here is selection of the active medium, liquid nitrogen or oxygen and compressed hydrogen or deuterium being most suitable. Pumping radiation from a neodymium laser or from a dye laser can thus be readily shifted into the near or intermediate infrared region of the spectrum, a high-power tunable infrared laser being ultimately desired. The tuning range can be extended further into the long-wave direction by two-stage Raman scattering with the converted radiation of one laser pumping another active medium, which is theoretically simple but practically very difficult. Another application for stimulated Raman scattering as well as for stimulated Mandelshtam-Brillouin scattering is phase conjugation to achieve wavefront reversal, a method of compensating wavefront distortions produced during passage through an optically nonhomogeneous medium on the basis of "repetition effects" and a method representing a special use of nonlinear optics. Wavefront reversal by stimulated scattering is limited by transverse modulation, which causes mismatch of the wave vectors of incident and scattered light, as well as by their different polarizations, which complicates the mechanism. Wavefront reversal is useful in various areas, primary among them being improvement of visibility in a turbulent scattering atmosphere, improvement of the performance of optical amplifiers in power laser systems, and automatic guidance of laser radiation onto a thermonuclear target for controlled fusion. The phenomenon of hyper-Raman scattering though weak spectral lines in both Stokes and anti-Stokes ranges, based on fundamental-frequency pumping and a two-photon process or, in nonlinear crystals, possibly a three-photon process, is particularly useful for spectroscopy of crystals such as NH_4Cl. It is of practical interest especially because of resonance effects, and also because of its peculiar temperature dependence in ferroelectric crystals which allows it to occur not only below but also above the Curie point. Figures 11; tables 1;

references 17 (11,12,29-43): 13 Russian, 4 Western; also chapters III ("Stimulated Raman Scattering of Light") and V ("Stimulated Molecular Scattering of Light").

[135-2415]
/12379

UDC 535.2

THEORY OF MODIFIED STIMULATED PHOTON ECHO IN Yb VAPOR IN LONGITUDINAL MAGNETIC FIELD

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 288, No 4, May 86 (manuscript received 17 Jun 85) pp 857-861

[Article by I.V. Yevseyev and V.N. Tsikunov, Moscow Institute of Engineering Physics]

[Abstract] Modified stimulated photon echo in a gaseous medium is considered, such an echo being produced by three pulses: two pulses with carrier frequency ω_1 and resonance frequency ω_0 of optically allowed b→a transition, one pulse with carrier frequency ω_2 and resonance frequency ω_0 of optically allowed b→c transition (energy levels $E_a<E_b<E_c$). A theory of such an echo at transitions with angular momenta at resonance levels $J_a = 0$, $J_b = 1$, $J_c = 1$ in a longitudinal magnetic field is constructed, these momenta corresponding to those at levels $^1S_0$, $^3P_1$, $^3S_1$ in ^{174}Yb atoms in the J.C.Keller-J.L.LeGouet experiment. Application of a constant longitudinal magnetic field facilitates separation of the echo signal from the third excitation pulse, inasmuch as the electric field of the echo signal has a component which then becomes normal to the polarization plane of the excitation pulses. Analysis of this phenomenon is based on calculation of the electric field intensity in the approximation of short pulse, the procedure being analogous to that for a plain photon echo in a uniform longitudinal magnetic field. The duration of each pulse is assumed to be much shorter than the characteristic time parameters of Zeeman splitting of resonance levels, namely the respective relaxation time and the reciprocal of the respective splitting frequency. Relations are obtained describing a modified stimulated photon echo with carrier frequency ω_2 and elliptic polarization, propagating in the direction in which the excitation pulses pass through the gaseous medium (Yb vapor). On the basis of this theory it is possible to evaluate the differences between relaxation characteristics at the b-level, caused by elastic depolarizing collisions, and subsequently the interaction potential which characterizes interaction of resonating atoms and buffer gas atoms. The authors thank V.M. Yermachenko for helpful discussions. Article was presented by Academician B.B. Kadomtsev on 11 June 1985. References 6: 4 Russian, 2 Western.

2415/12379
CSO: 1862/218

UDC 621.373.826

TWO-PHOTON RESONANCE SPECTROSCOPY OF VIBRATIONAL TRANSITIONS IN MOLECULES UNDER CONDITIONS OF FOUR-WAVE FREQUENCY MIXING

Moscow KVANTOVAYA ELEKTRONIKA in Russian Vol 13, No 5, May 86 (manuscript received 19 Jun 85) pp 887-899

[Article by V.S. Dolzhikov, Yu.S. Dolzhikov, A.A. Makarov, V.G. Movshev, and Ye.A. Ryabov, Institute of Spectroscopy, USSR Academy of Sciences, Troitsk (Moscow oblast)]

[Abstract] A nonlinear four-wave frequency mixing process is considered for spectroscopy of vibrational transitions in molecules, namely in active molecular media which absorb infrared radiation near resonance with two-photon transitions, a special case of this process being third-harmonic generation. Polarization of the medium is induced by infrared radiation at a frequency $2\omega_{IR}$ and this radiation together with simultaneously impinging visible radiation at a frequency ω_v can generate sum-frequency and difference-frequency radiation $\omega_s = \omega_v \pm 2\omega_{IR}$ within both anti-Stokes and Stokes ranges. The theory of this process is based on the three-level energy diagram for molecules with a cubically nonlinear susceptibility. In an experimental study of this process a transverse-excitation atmospheric-pressure CO_2-laser was used as source of infrared radiation pulses (energy up to 2 J, duration and waveform variable, repetition rate 6.25 Hz) with discrete wavelength tuning by means of a diffraction grating inside the resonator cavity, and a YAG:Nd-laser was used as source of visible radiation pulses (wavelength λ = 532 nm, maximum energy approximately 40 mJ, duration τ_v = 10 ns) with frequency doubling. The duration and the waveform of CO_2-laser pulses were varied by varying the nitrogen concentration in the active mixture. The two lasers were synchronized so as to allow variation of the time lag between their pulses over a wide range from 20 ns to 4 μs. Measurements were made with the two lasers in a collinear geometrical configuration and their axes of polarization at right angle to one another, with a triple spectrometer suppressing the second-harmonic radiation from the YAG:Nd-laser, and with the pumping radiation preattenuated by means of an optical interference filter before the spectrometer slit. The spectrometer output signals were recorded by a multichannel spectrum analyzer with an SIT-500 receiver and a WP-4 spectrum processor. Weak signals were allowed to build up on the cooled detector target for a period of up to 10 min. This method of spectroscopy was tested on four gases: SF_6, BCl_3, CF_3Br, CF_3I under pressures of 0.1-4 mm Hg in a variable-length test cell with NaCl windows. An evaluation of the data has yielded the dependence of the intensity of combination-frequency signals on the energy density of CO_2-laser radiation at the resonance line, with either constant time lag between CO_2-laser and YAG:Nd-laser pulses or constant CO_2-laser radiation intensity during probing, on the pressure of the test gas, on the intensity of YAG:Nd-laser second-harmonic radiation, and on the CO_2-laser radiation wavelength. Further calculations for the nine contributing channels, based on the theory of perturbations, reveal a signal spectrum much narrower than the Q-branch of two-photon resonance at room temperature. This can be very helpful in molecular spectroscopy of mixtures

whose components have overlapping infrared absorption bands or overlapping bands with different initial vibrational states of a molecule. The authors thank V.S. Letokhov for support and N.I. Koroteyev for helpful discussions. Figures 8; tables 2; references 14: 6 Russian, 8 Western (1 in Russian translation).

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USE OF SCANNING RADIATION FOR SMOOTHING SPECKLES IN DIFFUSE OBJECT IMAGES

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[Article by N.D. Ustinov, A.V. Anufriyev, Yu.A. Zimin, S.Ye. Kireyev, V.N. Lopatkin and A.I. Tolmachov "Use of Scanning Radiation for Smoothing Speckles in Diffuse Object Images"]

[Synopsis] The possibility of smoothing speckles in diffuse object images by using scanning radiation is studied theoretically and experimentally. It is shown that the smoothing occurs when radiation has one wave-length, and without deteriorating resolution. For all practical purposes, the images obtained are not different from those in white light.

[Text] It is well known that a diffuse object image in coherent light consists of a set of separate spots of various intensity randomly located in the image plane [1-3]. Such an image structure makes correct identification of an observed image difficult. A problem therefore arises of smoothing the image speckle-structure. It is possible to improve quality of an image by illuminating an object using radiation having a different wave-length [4]. However, this results in chromatic aberration. A method of three-dimensional averaging in the image plane is known; according to this method, the contrast range of spots is decreased at the expense of resolution [5]. The article studies the possibility of improving the image quality when using scanning radiation, without deteriorating the resolution.

We shall assume that the object under consideration is illuminated by a radiation sourse with aperture Ω and the three-dimensional distribution of the field $A(x)$ over the aperture, where x is a coordinate in the aperture plane. In the x-plane field phase disturbances of the exp $[2\pi a(t)x]$ form can be introduced, where the a(t) vector determines the slope of the wave front and, in the case of scanning, is a function of time t. Then incident electromagnetic field in the image plane of the analyzed object r is [5]

$$B(r, t) = \frac{1}{i\lambda R_0} \int_{\Omega} A(x) \exp[ik(R_0 + |r - x|^2/2R_0) + i2\pi a(t)x]\, dx, \qquad (1)$$

where R_0 is the distance to the object; λ is the wave-length; $k = 2\pi/\lambda$. The field scattered by the object is

$$E(r, t) = b(r, t) R(r), \qquad (2)$$

where R(r) is a complex amplitude reflection factor of the object.

During the time of registration of radiation scattered by the object, scanning of illuminating radiation occurs in such a way that the a(t) vector runs through the Ω_a region that contains the point a=0. In this case registration time averaging is equivalent to vector a averaging. If the condition $(S_a S)^{1/2} \gg 1$ (S_a and S are areas of Ω_a and Ω regions) is met, then the following relationships are true for the field scattered by the object:

$$\overline{E(\mathbf{r})} = \frac{1}{S_a}\int_{\Omega_a} E(\mathbf{r})\,d\mathbf{a} = 0,\ \overline{E(\mathbf{r}_1)E(\mathbf{r}_2)} = \overline{E^*(\mathbf{r}_1)E^*(\mathbf{r}_2)} = 0,$$

$$\overline{E(\mathbf{r}_1)E^*(\mathbf{r}_2)} = \frac{1}{S_a(\lambda R_0)^2} R(\mathbf{r}_1)R^*(\mathbf{r}_2)\exp\left[i\,k\,(|\mathbf{r}_1|^2 - |\mathbf{r}_2|^2)/2R_0\right]\int_{\Omega}|A(\mathbf{x})|^2 \times \exp\left[-ik\mathbf{x}(\mathbf{r}_1-\mathbf{r}_2)/R_0\right]d\mathbf{x}, \quad (3)$$

where the bar over a term denotes image registration time averaging. We shall assume that the analyzed object image is formed by the receiving aperture Ω_{np} with the area of S_{np} located next to the object illuminating aperture and that the condition of good object resolution $S_0 S_{np}/(\lambda R_0)^2 \gg 1$ is met, where S_0 is the area of the object projection Ω_0 onto the image plane. For effective smoothing of speckle-structure in the observed object image it is necessary for the correlation function of the scattered field $\overline{E(\mathbf{r}_1)E^*(\mathbf{r}_2)}$ to differ from zero only in a small region of argument $\mathbf{r}_1-\mathbf{r}_2$ values, and the size of the correlation region has to be smaller than the size of the element of object resolution by the receiving aperture. This condition can be met with no hardship in some of the following cases.

1. $|A(x)|^2=1$ in the Ω region. The area of the illuminating aperture is comparable to that of the receiving one. Then

$$\overline{E(\mathbf{r}_1)E^*(\mathbf{r}_2)} = R(\mathbf{r}_1)R^*(\mathbf{r}_2)\exp\left[ik(|\mathbf{r}_1|^2-|\mathbf{r}_2|^2)/2R_0\right] S\,/\,h(\mathbf{r}_1-\mathbf{r}_2)/S_a(\lambda R_0)^2, \quad (4)$$

where $h(\mathbf{r}) = \frac{1}{S}\int_{\Omega}\exp(ik\mathbf{r}\mathbf{x}/R_0)\,d\mathbf{x}$. To determine the contrast range of spots we will find the image registered in the ρ-plane averaged over realizations of microstructure of a diffuse object [5]:

$$\langle\overline{J(\boldsymbol{\rho})}\rangle = \frac{S\,/\,S_{np}^2}{2\lambda^6 R_0^4 z^2 S_a}\int_{\Omega_0}\int_{\Omega_0}\langle R(\mathbf{r}_1)R^*(\mathbf{r}_2)\rangle\exp\left[i\frac{k}{R_0}(|\mathbf{r}_1|^2-|\mathbf{r}_2|^2)\right]h_{np}^*\left(\mathbf{r}_1+\right.$$

$$\left.+\frac{R_0}{z}\boldsymbol{\rho}\right)h_{np}\left(\mathbf{r}_2+\frac{R_0}{z}\boldsymbol{\rho}\right)h(\mathbf{r}_1-\mathbf{r}_2)\,d\mathbf{r}_1\,d\mathbf{r}_2 = \frac{S\,/\,S_{np}^2}{2S_a\lambda^4 R_0^2 z^2}\,U\left(-\frac{R_0}{z}\boldsymbol{\rho}\right), \quad (5)$$

where $h_{np}(\mathbf{r}) = \frac{1}{S_{np}}\int_{\Omega_{np}}\exp\left(i\frac{k}{R_0}\mathbf{r}\mathbf{y}\right)d\mathbf{y}$; z is the distance from the receiving aperture to the image plane; $\langle R(\mathbf{r}_1)R^*(\mathbf{r}_2)\rangle = U(\mathbf{r}_1)\delta(\mathbf{r}_1-\mathbf{r}_2)$, $U(\mathbf{r}_1)$ is proportional to the object's reflection factor in regards

intensity, and the brackets denote averaging over various realizations of the object surface microstructure. We can similarly calculate

$$\langle \overline{J(\rho)}\,\overline{J(\rho)}\rangle = \langle \overline{J(\rho)}\rangle\langle \overline{J(\rho)}\rangle + \frac{1}{4}\left(\frac{S_{np}}{\lambda^2 R_0 z}\right)^4 \left(\frac{l\,S}{S_0\lambda^2 R_0^2}\right)^2 \times$$

$$\times \int_{\Omega_0}\int_{\Omega_0} U(r_1)\,U(r_2)\,|h(r_1-r_2)|^2 \left|h_{np}\left(r_1+\frac{R_0}{z}\rho\right)\right|^2 \left|h_{np}\left(r_2+\frac{R_0}{z}\rho\right)\right|^2 dr_1\,dr_2 =$$

$$= \begin{cases} \langle \overline{J(\rho)}\rangle^2\left(1+\dfrac{S_{np}}{S}\right) \text{ при } S \geqslant S_{np}; \\ 2\langle \overline{J(\rho)}\rangle^2 \text{ при } S < S_{np}. \end{cases} \qquad (6)$$

The contrast range of spots in the image is equal to

$$K_1 = \frac{(\langle \overline{J(\rho)}\,\overline{J(\rho)}\rangle - \langle \overline{J(\rho)}\rangle\langle \overline{J(\rho)}\rangle)^{1/2}}{\langle \overline{J(\rho)}\rangle} = \begin{cases} \left(\dfrac{S_{np}}{S}\right)^{1/2} \text{при } S_{np} \leqslant S; \\ 1 \quad \text{при } S_{np} > S. \end{cases} \qquad (7)$$

We have thus derived that the efficiency of smoothing the spotty structure of an image is high when the aperture used for illuminating the object is significantly larger than the receiving one. It should be noted that phase distortions of object illuminating radiation (that can be due to poor optics or the atmosphere) do not affect the process of smoothing the spotty structure, as in expression (3) for the correlation function only the square of the absolute value of the brightening field $|A(x)|^2$ is present. Therefore a low-quality aperture can be used for illumination.

2. The object is illuminated by a square matrix of dotted apertures. The linear dimension of the matrix is l, the distance between adjacent apertures (base size) is l_0 ($l_0 \ll l$). Assuming that the receiving aperture is a square l_{np} on side, we can derive the contrast range of spots similarly to case 1:

$$K_2 = \begin{cases} 1 & \text{at } l_{np} \geqslant l, \\ l_0/l & \text{at } 2l_0 > l_{np}; \\ l_{np}/l & \text{at } l > l_{np} > 2l_0. \end{cases} \qquad (8)$$

3. Brightening by a linear sequence of dotted apertures with a total length l and base l_0. In this case

$$K_3 = \sqrt{K_2}. \qquad (9)$$

These results can be explined as follows. In the absence of phase distortions of the object illuminating radiation, successive scanning of one resolution element of the object by a small spot (cases 1 and 2) or by a narrow band (case 3) occurs. Under these conditions, radiation scattered by various areas of the surface microstructure of one resolution element is successively registered in one point of a plane. In the presence of phase distortions the illumination field in the image plane of the object is aspatially random spotty picture. The characteristic dimension of a spot is determ-

ined by the size of the aperture used for illumination. At different moments in time during the scanning, different areas of the same object resolution element are illuminated. This leads to smoothing the speckle-structure of the image. The degree of smoothing is determined by the ratio of areas of object resolution element of the receiving aperture and the scanning spot (or band).

The possibility of using scanning radiation for improving quality of coherent images has been studied experimentally. The experimental unit diagram is shown in Fig.1. A copper vapor laser beam 1 (λ=0.51μm) diverged by a microscope objective 2 with a point diaphragm 3 and collimated by an objective 4 **strudk a slit** diaphragm 5 that was used for simulating case 3. After passing the slit diaphragm 5, radiation illuminated a narrow band of a diffuse object 6. The object was made of aluminum foil sanded with fine sand paper. At a distance R_0= 468 cm from the object a square aperture diaphragm 7 l_{ap} =3 mm on the side and an objective 8 with a focal length f=300 mm were located. The objective 8 **formed an** an image of the object 6. This image, enlarged by a microscopic objective 9, was registered on film by a camera 10.

Using a transverse movement of the slit diaphragm 5, scanning of a light band over the object surface was performed. The size of the slit diaphragm was selected such that the width of the light band on the surface of the object be smaller than the linear size of the resolution element. To get an extremely narrow band, a focusing cylindrical lens was used instead of a slit diaphragm. Fig.2 shows the images of the square object that were obtained. It can be seen that when the width of the light band decreases, the coherent image of a diffuse object gets closer to its image in white light. **The possibility** of improving the image quality by scanning the object surface with a field having a spotty structure (simulation of case 1) was examined. In order to do that, a polyethylene phase screen and a scanning mirror were placed behind the objective 4, instead of the slit diaphragm. In this case too good smoothing of the speckle **image** was observed.

These theoretical and experimental studies proved that the use of scanning radiation makes it possible to smoothen the speckle-structure of coherent images of diffuse objects. The smoothing occurs by using radiation having one wave-length, and resolution does not deteriorate. For all practical purposes, the obtained images are not different from those obtained in white light.

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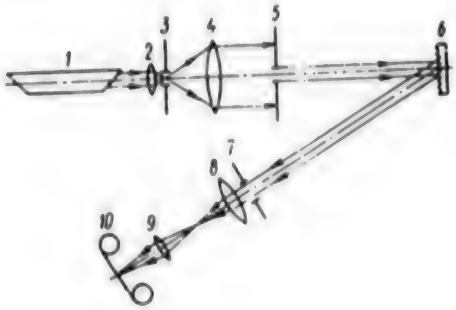

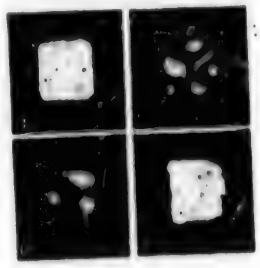

Fig.1. The experimental unit diagram.
Fig.2. Experimentally obtained images of a square object 3x3 mm in white light (a), in coherent light without smoothing (б), with smoothing, using a slit diaphragm 0.2 mm wide (b) and with smoothing, using a cylindrical lens (г)

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ON POSSIBLE APPLICATIONS OF MÖSSBAUER SPECTROSCOPY FOR THE DETERMINATION OF SOUND FIELD TOPOGRAMS IN LIQUIDS

Yerevan IZVESTIYA AKADEMII NAUK ARMYANSKOY SSR in Russian Vol 20, No 5, Sep-Oct 85 pp 278-281

[Article by A.R. Arakelyan and E.M. Arutyunyan, Institute of Applied Problems of Physics, Academy of Sciences of the Armenian SSR, and M.M. Slavinskiy, Institute of Applied Physics, Academy of Sciences of the USSR: "On Possible Applications of Mössbauer Spectroscopy for the Determination of Sound Field Topograms in Liquids"; received 6 July 1984; the first paragraph is a summary]

[Text] The paper is an experimental study of the possibility of estimating the characteristics of sound fields in liquids on the basis of modulating Mössbauer gamma-resonance radiation by external acoustic vibrations. It has been demonstrated that Mössbauer spectroscopy allows measuring with a high accuracy the characteristics of sound fields in liquids, namely: the distribution of the sound field in the liquid, the directional diagram of the sound source in the liquid, the propagation velocity of acoustic vibrations and the electroacoustic conversion factor, etc. The investigation was conducted in water. The results obtained are consistent with the available data.

The excitation of acoustic vibrations with a frequency smaller than the absorption line width in Mössbauer absorbers is known to affect significantly the form of Mössbauer absorption spectra [1]. The parameters of external vibrations are also affected.

This effect is explained by the following mechanism. Under the action of acoustic vibration, the absorber vibrates with a velocity that varies periodically in relation to the source of the gamma-quanta. In that case, the shape of the absorption line is described by the expression

$$F(\omega) = 1 - \frac{1}{T}\int_0^T \frac{dt}{\frac{\omega-\omega_0}{\Gamma/2} - \frac{v(t)}{\lambda\Gamma/2}^2 + 1}, \qquad (1)$$

where $\omega = \omega_0 v/s$, v is the velocity of the source of the gamma-quanta, ω_0 is the resonance gamma-quanta frequency, λ is the reduced wavelength of the gamma-quanta, $v(t)$ is the velocity of external excitation vibration, $\Gamma/2$ is half-width of the absorption line and c is the light velocity. It is seen from (1) that the form of the absorption spectrum is determined by the external excitation, so that, by modifying the form of the Mössbauer spectrum, one can find the parameters of the external acoustic vibrations.

Under the effect of acoustic excitation, a single absorption line of gamma-radiation is first broadened and then, under certain amplitude (or frequency) values, the shape of the line changes completely, resulting in two minima. The distances between the minima increase with increasing amplitude of external vibration. As the vibration amplitude continues the rise, the minima decrease and become of the same order of magnitude as the noise.

This paper investigates one such possibility of studying the formation and propagation of low-frequency vibrations in a water medium.

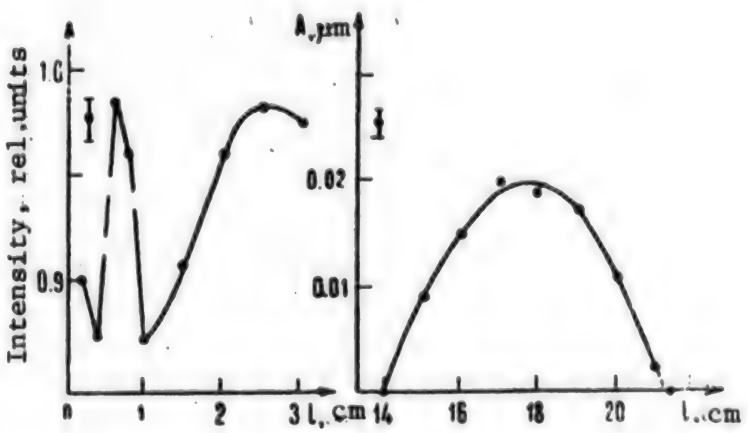

Figure 1. The intensity of Mössbauer absorption line versus distance to the excitation source near and far from the source.

For investigating the sound fields in liquids, a special tank was built with a vibrator for exciting acoustic vibrations. The sensor of acoustic vibrations immersed in the water was made as a disk of aluminum foil 10 mm in diameter, climinated "Rigidly" to the Mössbauer absorber and placed outside the water medium.

In order to improve the sensitivity of the detection of mechanical vibrations and their transmission to the Mössbauer absorber, special efforts were undertaken to reduce the friction at the suspension point. The arms of the suspension unit were precisely equalized. To ensure detector stability during the registration of vibrations the center of gravity of the receiver-transmitter system was placed slightly below the suspension point.

The experiments were staged in ordinary water at frequencies above the resonance frequency ($\Omega_{res} = 4$ kHz) of the exciter at low amplitudes. In our experiment at a frequency of 10 kHz it was 5×10^{-8} cm/V. The results of intensity measurements at the minimum point of the Mossbauer absorption line for various distances from the sound vibration source are shown in fig. 1.

It is seen from the figure that oscillations of the sound field intensity occur near the source within the tank caused by the interference of waves propagating from different points of the vibration source [2, 3]. With increasing distance from the source, the sound field "stabilizes" (see fig. 1), and a complete reproduction of the wave formula takes place, making it possible to measure the wavelength. The picture in the figure represents the time averaging of absorption spectra for the statistics of 10^5 quanta in the channel. After determining the wavelength and knowing the vibration frequency, the sound propagation velocity can be found. The acoustic vibration velocity measured in this way in the water was (1483 ± 11) m/s. This result is consistent with the available published data [2, 3].

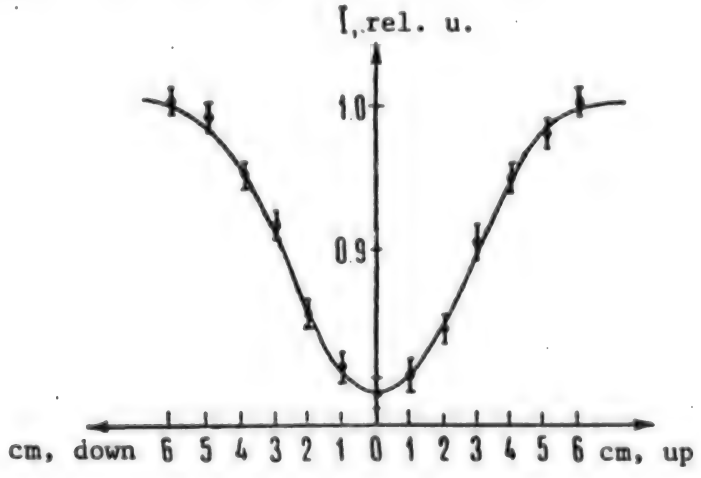

Figure 2. Topograms of the acoustic field in the direction perpendicular to wave propagation.

Measurements of sound fields were also made at various depths in the cross-section of the acoustic beam, producing a topogram of the field in the water. Figure 2 presents the results of these measurements at a distance of 18 cm from the sound field source.

A similar investigation has also been conducted in the frequency range of 150-250 Hz. Figure 3 shows the intensity of the Mössbauer absorption line and the respective amplitude as a function of the voltage on the converter for a constant frequency and also the intensity of the absorption line and the

amplitude as a function of the acoustic excitation frequency for a constant voltage on the converter. The error in amplitude determination is due to the statistical error of the set of gamma-quanta.

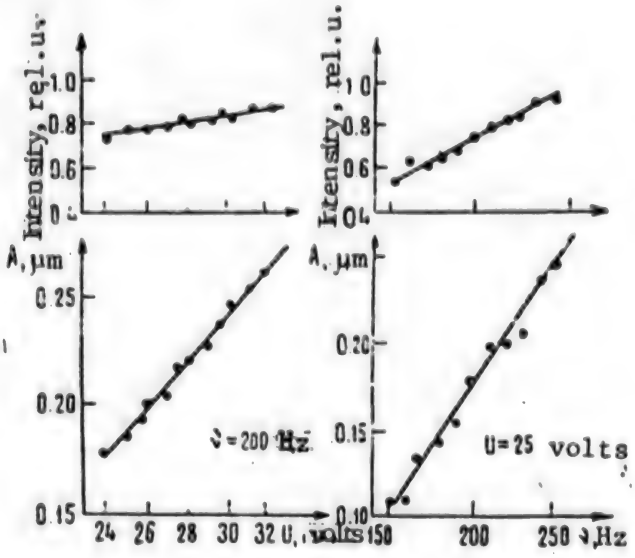

Figure 3. The intensity of the Mössbauer absorption line and the respective amplitude versus voltage on the converter at a constant frequency and versus frequency at a constant voltage.

This study has shown that the method of gamma-acoustic spectroscopy can be used to measure the characteristics of sound fields in water media with a good accuracy.

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COMPRESSION AND HEATING OF LASER PLASMA ALONG AXIS OF CONICAL TARGET

Moscow FIZIKA PLAZMY in Russian Vol 12, No 1, Jan 86 (manuscript received 14 Jan 85, after correction 8 May 85) pp 33-37

[Article by A.G. Bonch-Osmolovskiy and V.A. Monchinskiy, Joint Institute of Nuclear Research]

[Abstract] Formation and buildup of a dense and hot plasma in a solid target of conical shape under a laser beam is analyzed, assuming that such a plasma is a near-ideal gas. The laser radiation is focused onto the base of the cone and the plasma jet flowing in the direction of the cone axis expands at a rate higher than the speed of sound so that quasi-cylindrical collisions of supersonic plasma particles occur on the cone axis. In a cone with a smaller then critical vertex angle $\alpha < \tan^{-1}(1/\sqrt{\gamma^2 - 1}$ (γ - adiabatic exponent) a large part of the kinetic energy will be converted into heat along the axis and no cumulative plasma jet will be formed. The temperature and the density of such a noncumulative plasma jet after collisions are estimated, assuming a near-stationary laboratory system with a concentration of charge carriers $n \ll 10^{23}$ cm^{-3}, $\alpha_{crit} = 37°$, and $\gamma = 5/3$ or slightly less on account of internal degrees of freedom (excitation and ionization). The analysis is based on two equations of electron-ion relaxation and energy conservation with two unknowns, namely the rates of change of electron temperature and ion temperature, and with pressure as an implicit parameter. Solution of these equations for the appropriate initial conditions yields the two plasma temperatures as functions of time through the compression period, during which both electron temperature and ion temperature increases, and the subsequent relaxation period, during which the higher ion temperatures drops fast and the lower electron temperature continues to rise but at an increasingly slower rate, until both temperatures converge to and level at the common temperature of adiabatic collisions. Results of numerical calculations and experimental data pertaining to a conical magnesium target with a vertex angle of approximately 30° under a CO_2-laser beam of 10^{12} W/cm^2 effective intensity (effective power density on the cone surface approximately 5 10^{11} W/cm^2) indicate a high degree of ionization with a large quantity of Mg^{+11} or even Mg^{+12} ions and formation of a dense

and hot plasma with $n \gtrsim 10^{19}$ cm^{-3} and $T_e \sim (4-5) \cdot 10^6$ K, and with a lifetime of the order of 10 ns. Figures 1; references 13: 8 Russian, 5 Western (2 in Russian translation).

[128-2415]
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THEORY OF SOLITONS ENVELOPING ELECTROMAGNETIC WAVES IN MAGNETICALLY ACTIVE PLASMA

Moscow FIZIKA PLAZMY in Russian Vol 12, No 1, Jan 86 (manuscript received 25 Dec 84, after completion 29 Apr 85) pp 43-47

[Article by S.V. Kuznetsov]

[Abstract] Nonlinear one-dimensional motion of a magnetically active plasma is analyzed by considering an electromagnetic wave with circular polarization and describing it with the aid of both scalar potential ϕ and vector potential A, letting div A = 0 and assuming a constant unidirectional magnetic field. Solution of the resulting equations of motion for the electron component and for the ion component yields, after determination of the integration constants, envelope solitons propagating in the direction of the magnetic field. The solution, a second-order differential equation with cubic nonlinearity, is analyzed for existence of such solitons within the regions of Alfven plasma oscillations and fast magnetoacoustic plasma oscillations in the cyclotron-plasma frequency plane. These regions of soliton existence are determined by nonlinearities resulting from longitudinal motion of the plasma and by motion of relativistic plasma. The author thanks Yu.M. Aliyev for discussion and valuable comments. Figures 1; references 6: 5 Russian, 1 Western.

[1281-2415]
/12379

SELF-SUSTAINED OSCILLATIONS IN CONFINED PLASMA-BEAM SYSTEM

Moscow ZHURNAL EKSPERIMENTALNOY I TEORETICHESKOY FIZIKI in Russian Vol 90, No 1, Jan 86 (manuscript received 5 Apr 85) pp 25-34

[Article by V.S. Gvozdetskiy, V.P. Kovalenko, and I.M. Parneta, Institute of Electric Welding imeni Ye.O. Paton, Ukrainian SSR Academy of Sciences, Institute of Physics, Ukrainian SSR Academy of Sciences]

[Abstract] An interpretation is developed for the previously unexplained nonlinear process of self-generated oscillations in a plasma-beam system of finite length. Electron beam grouping in a counter-propagating wave is analyzed. The predicted discreteness of the spectrum of the possible

oscillation frequencies is verified experimentally. The eigenfrequencies of the system are found numerically, and the amplitudes of the corresponding waves are calculated. Figures 8, references 15: 11 Russian, 4 Western.

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DETERMINATION OF CURRENT PROFILE IN PLASMA BY PROBING WITH HEAVY-ION BEAMS

Moscow FIZIKA PLAZMY in Russian Vol 12, No 6, Jun 86 (manuscript received 5 Jul 85) pp 687-692

[Article by Yu.N. Dnestrovskiy and A.V. Mel'nikov]

[Abstract] Plasma probing with beams of heavy ions has been proposed for determining the current profile in a plasma, a "primary" ion beam being injected transversely to the sustaining magnetic field and a detector collecting "secondary" waves which exit from the plasma after having separated from the beam along trajectories with different radii of curvature. These waves carry information about the current profile or the poloidal magnetic field of the plasma as well as about the electric potential distribution, the electron concentration, and the electron temperature. This method has already been applied to determination of the poloidal magnetic field in the stellarator tokamak with a beam of Tl^+ ions. It is now considered for determining the field of plasma current in a tokamak from the deflection of the probing beam by this field. The method is based on the equation which relates the sought toroidal magnetic vector potential to the measurable toroidal displacement of probing particles between injection point and detection point, a nonlinear integral equation of the second kind. This equation is derived from the Lagrange equation describing the motion of probing particles in a cylindrical system of coordinates, r,ϕ,z where the z-axis coincides with the principal torus axis, assuming an ideal tokamak without corrugations. Three basic measurement problems can be formulated for this equation: 1) measurements made with a detector grid covering the entire plasma cross-section, 2) measurements made with a detector line between the plasma boundary and the magnetic axis, 3) all intermediate configurations of only several detector lines not covering the entire plasma cross-section. A special case is a current-carrying torus degenerated into a straight cylinder. The constraint of plasma stability results in a tokamak with the toroidal field one order of magnitude stronger than the poloidal field and in a longitudinal displacement of the probing beam negligible in comparison with its meridional displacement. The integral equation for the magnetic vector potential can then be linearized and easily solved by the method of iterations. This has been done for the TUMAN-3. The authors thank L.I. Krupnik and K.A. Razumova for formulating the problem and discussing the analysis. Figures 3; references 4: 1 Russian, 3 Western.

2415/12379
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UDC 533.9.01:538.4

INFLUENCE OF DEFORMATION OF PLASMA DENSITY PROFILE BY GENERATION OF QUASISTATIONARY MAGNETIC FIELD

Moscow FIZIKA PLASMY in Russian, Vol 12, No 7, Jul 86 (manuscript received 22 Oct 85) pp 821-826

[Article by A.V. Kochetov, A.G. Litvak, A.M. Feygin, and A.V. Khimich, Institute of Applied Physics, USSR Academy of Sciences]

[Abstract] The magnitude of the quasistationary magnetic field is found as a function of the intensity of the incident radiation within the framework of the one-dimensional model for the case in which displacement of a plasma from the resonant region by the effect of ponderomotor force is significant. Analytical estimates are obtained, and confirmed by computer, for weak and strong deformation. Figures 2, references 13: 8 Russian, 5 Western.

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LONGITUDINAL WAVE SPECTRUM IN HOT DEGENERATE PLASMA

Moscow FIZIKA PLASMY in Russian, Vol 12, No 7, Jul 86 (manuscript received 18 Sep 85 after revision) pp 814-820

[Article by D.G. Lominadze, G.I. Melikidze, V.P. Silin, and V.N. Ursov, Abastuman Astrophysical Observatory, Georgian SSR Academy of Sciences, Physics Institute imeni P.N. Lebedev, USSR Academy of Sciences]

[Abstract] The solutions of the dispersion equation for longitudinal waves in a degenerate plasma are investigated within the framework of classical mechanics in both the relativistic and nonrelativistic cases over the entire interval of wave vector magnitudes from zero to infinity. The findings obtained previously for the spectrum of longitudinal waves in a degenerate Fermi plasma are found to be applicable for finite temperatures that do not violate plasma degeneration, but only for wave phase velocities that are not too close to the Fermi velocity. The present study describes the longitudinal wave spectrum with allowance for thermal motion for phase velocities which are close to the Fermi velocity. It is shown that solutions exist for the dispersion equation for any values of the wave vector, but that the phase velocity of the longitudinal waves approaches other than the Fermi velocity as the wave vector increases. In contrast to a nonrelativistic Boltzmann plasma,

determination of the spectrum of the waves in question may not be associated with strong Landau attenuation. Figures 4, references 14: 12 Russian, 2 Western.

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X-RADIATION AND ELECTRON TEMPERATURE OF LASER PLASMA CREATED BY ULTRASHORT PULSES

Moscow FIZIKA PLASMY in Russian, Vol 12, No 7, Jul 86 (manuscript received 20 Sep 85 after revision) pp 860-865

[Article by A.N. Kirkin, R.G. Mirzoyan, and A.M. Mozharovskiy, Physics Institute imeni P.N. Lebedev, USSR Academy of Sciences]

[Abstract] The line spectra of laser plasma is analyzed considering the presence of T_e and N_e inhomogeneities contained. The line and continuous spectra of the X-radiation of the plasma created by ultrashort pulses from an Nd:YAG laser with a pulse length of τ_p = 40 psec and radiation strength at the target I_p of up to $5 \cdot 10^{14}$ W/cm^2 were investigated. The values of T_e found from the line and continuous spectra were compared. T_e was estimated in the supercritical region and the plasma corona close to the critical point. It was found that existing plasma diagnostic methods using the relative intensities of the X-ray spectral lines do not identify the profiles of T_e and N_e correctly close to the critical point given the spatial resolution now attainable. Resolution of approximately 1 μm is needed in order to determine the N_e and T_e profiles correctly in this region.

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ANOMALOUS BEHAVIOR OF HALL EMF IN UBe_{13} AT LOW TEMPERATURES

Moscow PISMA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian (manuscript received 11 Apr 86) pp 482-484

[Article by N.Ye. Alekseyevskiy, Institute of Problems in Physics, USSR Academy of Sciences, A.V. Mitin, Institute of Spectroscopy, USSR Academy of Sciences, and F.G. Aliyev, N.B. Brandt, M.K. Zalyalyutdinov, V. Kovachik, V.V. Moshchalkov, S.M. Chudinov, Moscow State University imeni M.V. Lomonosov]

[Abstract] A superconducting system with heavy fermions was studied, such systems being characterized by an extremely narrow giant peak of electron states density near the Fermi level with an energy scale T^* of the order of 10 K and thus 10^2-10^3 times smaller than the width of the conduction band in normal metals. Buildup of this peak with a drop of the temperature below T^* has been found to be accompanied by an anomalous increase of the Hall emf, until scattering by f-ions becomes coherent when they have formed a periodic array of magnetic centers with an accompanying decrease of electrical resistivity, magnetic susceptibility, and electron specific heat as well as by a sign reversal of the thermal emf. As a specific such system was selected UBe_{13}, with a 15 mK wide temperature range of superconducting transition. Single crystals of this material, 0.3x2x6 mm^3 in size, were placed in a ^4He helium cryostat with a 140 kOe superconducting solenoid for measurements at temperatures above 1.5 K or in a ^3He-^4He helium refrigerator with automatic control for measurements over the $0.05 \leq T \leq 2.5$ K temperature range, to pinpoint the transition from noncoherent to coherent scattering at a temperature $T_{coh} < T^*$. The results indicate a drastic restructurization of the quasi-particle spectrum in UBe_{13} within the T T^* temperature range, with a large decrease of the Hall emf upon transition to coherent scattering. Without a theory of coherent scattering in systems with heavy fermions available, it is not possible to explain this anomaly of the Hall emf. The authors thank D.I. Khomskiy and A.I. Buzdin for discussion of the results. Figures 2; references 9: 3 Russian, 6 Western.

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EXOTIC SUPERCONDUCTORS

Moscow NOVOYE V ZHIZNI, NAUKE, TECHNIKE: SERIYA FIZIKA in Russian No 5, May 86 pp 100-101

[Excerpt from an article by Candidate of Physical and Mathematical Sciences Aleksandr Ivanovich Buzdin and Doctor of Physical and Mathematical Sciences Viktor Vasil'yevich Moshchalkov, Associates of the Low Temperatures Department of the Physics Department of Moscow State University]

[Text] Superconductors of Heavy Fermions

The discovery of magnetic superconductors, whose properties have been described in the preceding chapter, have shown convincingly that established notions about the antagonism of magnetism and superconductivity need to be substantially reworked. When specified conditions are fulfilled, superconductivity and magnetism may coexist: superconductivity is preserved in magnetic superconductors despite the occurrence of magnetic ordering. However, in the process, different electrons, or stated otherwise, different groups of charge carriers, are responsible for superconductivity and magnetism: superconductivity occurs as a consequence of the formation of Cooper pairs by valence, collectivized electrons with outer shells, whereas magnetism is related to the presence of a set of "elemental magnetics," which are magnetic moments of the inner electron shells of rare earth elements entering into the structure of magnetic superconductors.

Another discovery, which was made in 1979, compelled us to view the problem of the interconnection of magnetism and superconductivity differently. F. Shteglikh discovered a superconductor (the compound $CeCu_2Si_2$, $T_c = 0.5$ K) that distinctly manifests magnetic properties of the deep electron shells of cerium ions at high temperatures. It seemed as if upon a decrease of the temperature the "magnetics" of these shells must "couple" with one another and the compound itself must pass into a magnetic state. In addition, at low temperatures, the compound $CeCu_2Si_2$ passed into a superconductive state.

Detailed investigation of the properties of $CeCu_2Si_2$ in normal and superconductive phases made it possible to conclude that, in this compound, one and the same electrons placed into the valence band by the electron f-shell of serium ions were responsible for both the superconductivity at low temperatures and the magnetic properties at high temperatures. In other words, a situation that is paradoxical at first glance occurs in them: both superconductivity and magnetism are related with one and the same group of charge carriers, i.e., super-

conductivity exists thanks to the presence of magnetic ions. Moreover, adding a total of several atomic percents of nonmagnetic lanthanum ions to $CeCu_2Si_2$, which replace the cerium ions in this compound, completely suppresses superconductivity. We see that decreasing the concentration of magnetic centers sharply reduces the temperature T_c, whereas in ordinary superconductors it is the reverse--introducing an insignificant amount of magnetic centers completely suppresses superconductivity.

Heavy fermions. Upon further investigation of the properties of the unusual compound $CeCu_2Si_2$, it was possible to establish that in it superconductivity is related to the Cooper pairs that are formed by electrons (fermions) with a very high effective mass $m^* = (100\text{-}1{,}000)m_0$ (m_0 is the mass of the free electron). For comparison (Table 1), in normal metals $m^* = (0.1\text{-}1.0)m_0$.

Table 1. Comparison of the Characteristics of Typical Nonmagnetic Kondo Lattices ($CeCu_2Si_2$, $CeAl_3$, and UBe_{13}) and Normal Metal (Cu)

Металл (1)	$\gamma(T\to 0)$, мДж/моль · К² (2)	m^*/m_0	v_F, см/с (3)
$CeCu_2Si_2$	1050	500	$1{,}7\cdot 10^8$
$CeAl_3$	1620	800	$1{,}0\cdot 10^8$
$CeCu_6$	1450	10^2+10^3	$\sim 10^8$
UBe_{13}	1100	200	$3{,}4\cdot 10^8$
Cu	0,695	0,1—1,0	$0{,}57\cdot 10^8$

Key:

1. Metal
2. mJ/mol x K^2
3. v_F, cm/s

The energy bands in crystals occur as a consequence of the overlapping of the electron shells of atoms forming the crystal lattice. If this overlapping is great, the width of the band W is also great, the electron may easily move from one atom to another, and its effective mass is small. With a small overlapping of the shells, on the other hand, the band is narrow, and the motion of an electron from one lattice point to another is extremely impeded, i.e., m^* is great. We see that the effective mass is inversely proportional to the bandwidth.

The compound $CeCu_2Si_2$, in which the effective mass of the Fermi electrons is very great at low temperatures, $m^* = (100\text{-}1{,}000)m_0$, is customarily called a compound with heavy fermions and the unusual superconductivity of this compound described as "superconductivity in a system of heavy fermions" or the "superconductivity of heavy fermions." Up until now, three compounds in which such superconductivity is achieved have been identified: $CeCu_2Si_2$, UBe_{13}, and UPt_3. In the latter two compounds the magnetic moments of the internal f-shells of the uranium atoms are the "elemental magnetics." In addition, compounds with heavy fermions that do not pass into a superconductive state are also known: $CeAl_3$, $CeCu_6$, etc.

At low temperatures, the effective mass of the Fermi electrons is very great in all systems with heavy fermions (see Table 1). Inasmuch as the value of the mass m^* is inversly proportional to the width of the energy band, this means that in such systems there is a very narrow density peak of the giant-amplitude states on the Fermi level (Figure 9).

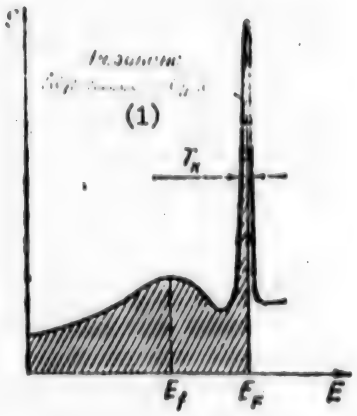


Figure 9. Schematic depiction of the behavior of the density of the states g(E) in concentrated Kondo systems.

Key:

1. Abrikosov-Sul resonance

The function g(E) determines the allowed number of energy states occurring in a single energy range. The value of g when $E = E_F$ may be determined experimentally from data on measurement of the heat capacity C of the metal at low temperatures where the heat conducted to the metal is transferred to both the crystal lattice (C_{ph} is the phonon contribution to the heat capacity) and the electron system (C_{el} is the electron contribution to heat capacity), with $C_{ph} = \beta T^3$ and $C_{el} = \gamma T$:

$$C = \gamma T + \beta T^3$$

where γ and β are the coefficients of the electron and lattice heat capacity respectively. At sufficiently low temperatures βT^3 is negligible compared with γT, and it is therefore possible to determine the coefficient γ of the electron heat capacity on the basis of the temperature dependence of C when $T \to 0$.

At low temperatures in metals, the heat may be absorbed effectively only by the Fermi electrons inasmuch as the free allowed energy levels (see Figure 1a) are arranged immediately after E_F. The larger the number of $g\Delta E$ Fermi, "active" electrons, the larger the amount of heat that must be conducted to the metal in order to increase its temperature by $\Delta T \sim \Delta E$. Thus, the coefficient of electron heat capacity is determined (with a precision up to the constant factor) by the density of the electron states on the Fermi level:

$$\gamma(T \to 0) \sim g\ (E_F). \qquad (1)$$

The value of γ in metals with heavy fermions (see Table 1) attains giant values, 1,000 to 1,600 mJ/mol x K^2, which exceeds the corresponding value in normal metal by two to three orders of magnitude. In other words, the density of the states on the Fermi level in systems with heavy fermions attains giant values (see Figure 9) compared with normal metals.

What is the reason for the appearance of this peak? Where are the heavy fermions in $CeCu_2Si_2$, $CeAl_3$, $CeCu_6$, UBe_{13}, and UPt_3 taken from? For the answer to these questions, it is worthwhile to examine systems of simpler, but nevertheless related compounds with heavy fermions. It should be noted in the

beginnning that in each elemental cell, all of these compounds contain an ion whose deep electron f-shell possesses an uncompensated magnetic moment, i.e., we are dealing with a periodic lattice of "elemental magnetics" located in a "sea" of collectivized electrons. Before trying to understand the essence of the physical processes occurring in such lattices, let us start by examining the behavior of one "elemental magnetic" immersed in a "sea" of conduction electrons.

Kondo's problem. As was mentioned in the introduction, the resistance ρ of normal metal decreases monotonically with a decrease in temperature. If a small quantity of impurity atoms that have an inner, well-localized electron shell possessing an uncompensated magnetic moment are introduced into such a metal, then a logarithmic growth in resistance is observed instead of a monotonical decrease in resistance with a reduction in temperature in the metal with magnetic impurities.

In 1964, the Japanese physicist and theoretician I. Kondo was the first to explain where this logarithmic dependence of ρ on temperature is taken from. It turned out that precisely such a dependence of resistance on temperature occurs during an examination of the dispersion of Fermi electrons of metal on a magnetic impurity. In the process of the collision and spin of a Fermi electron, the impurity "magnetic" is also flipped. Such a dispersion is frequently called a "Kondo dispersion with a spin flip." The very problem of the behavior of a magnetic impurity ("Kondo impurity") in a normal nonmagnetic metal has received the name "Kondo problem."

With a decrease in temperature, the contribution to the resistance by dispersion with an spin flip of $\Delta\rho \sim -\ln T$ is inconsistent inasmuch as when $T \to 0$, the logarithm tends to infinity. This result is in contradiction with the experimentally observed finite value of ρ when $T \to 0$. The reason for such a contradiction is that the exchange interaction I between the spins of the Fermi electron and the electron localized on the f-shell is viewed as a perturbation in Kondo's theory. This assumption is only valid for the range of not too low temperatures $T \gtrsim T_K$ at the same time as when $T \lesssim T_K$ where

$$T_K = T_F \exp\left\{-\frac{1}{g(E_F)I}\right\}, \qquad (2)$$

the electron localized on the f-shell and the Fermi electron with the opposite spin form a quasibound state for which Kondo's theory is entirely inappropriate. At the same same time, as A.A. Abrikosov and G. Sul have shown (1965), a narrow peak (with a width on the order of the Kondo temperature up to T_K) in the function of the density of the states (Abrikosov-Sul resonance), which corresponds to the Fermi electrons that "adhere" on the magnetic impurities forming a cloud of electrons with an opposite spin around them, forms on the Fermi level. Inasmuch as electrons with positively directed spins take part in the formation of the quasibound state, the sum spin of such a state equals zero.

We will examine a somewhat more detailed mechanism of the formation of a low-temperature nonmagnetic state ("Kondo singlet") and the formation of a peak in

the density of the states close to E_F (Figure 10). A narrow energy level, which falls against the background of the continuous spectrum of the conduction band of normal metal corresponds to the inner f-shell, which possesses a non-compensated magnetic moment.

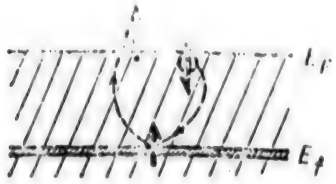


Figure 10. Kondo fluctuations in the spin of a localized electron on the magnetic level E_f through a state close to the Fermi level E_F

The orientation of the impurity spin many be changed in two ways: first, on account of "thermal failure" during which the "arrow" on level E_f, which corresponds to the impurity spin, is easily unsettled, interacting with the thermal excitation of the crystal lattice, the phonons. The characteristic time of the thermal breakdown of the orientation of the impurity spin will be designated as τ_T. Second, "vertical" transfers are possible (see Figure 10) in which an electron jumps from the magnetic level (from the f-shell) with a "↑" spin onto an unoccupied level located immediately over the Fermi level, and an electron with a "↓" spin "falls" from the filled level under E_F to the space vacated on the impurity magnetic level. This process corresponds to Kondo fluctuations in spin, i.e., to the inversion of the spin of the impurity passing through states close to E_F. The Kondo fluctuations in spin are completed in the time τ_{sf}.

How do the parameters τ_T and τ_{sf} relate to one another at different temperatures? At high temperatures where $T > T_K$, "thermal failure" occurs much more often that do Kondo fluctuations in spin ($\tau_T \ll \tau_{sf}$), and in all "rapid" temperature measurements, magnetic receptivity χ, heat capacity C, and resistance ρ, we will see an impurity spin with predominantly one direction, let us say "↑". At low temperatures $T < T_K$, we will be dealing with the reverse situation: $\tau_T \gg \tau_{sf}$ inasmuch as the thermal excitation "freezes out" when $T \to 0$. In this case, over the course of time τ_T, the impurity spin has time to change its orientation several times, and a distinctive smoothing occurs after this time, as a result of which, the effective impurity spin goes to zero. Characteristic anomalies, a logarithmic growth in resistance, the compensation of the impurity spin $\chi T \to 0$, and the supplementary contribution to heat capacity are observed in the temperature range where Kondo fluctuations in spin are inherent.

It is interesting that this participation of Fermi electrons also leads to a change in the state density of g close to the Fermi level. As the temperature decreases, the Fermi electrons are increasingly often replaced by locations with electrons of deep f-shells of the impurities responsible for the magnetism of these impurities. The radius of the localization of the t-shells is extremely small, a total of 0.3 to 0.4 Å, which is much less than the interatomic distance a ~5 Å in the crystal lattice. Therefore, the overlapping of the electron f-shells is very small, and it corresponds to the enormous effective mass $m^*_f \sim (10^3\text{-}10^4)m_0$. Now if the Fermi electrons regularly "jump" to the f-shell, this leads to a significant increase in their effective mass m* and to a growth in the density of the states of $g(E_F) \sim m^*$. Thus, the exchange of Fermi

electrons and electrons of the deep f-shells is essentialy the reason for the formation of an Abrikosov-Sul resonance $g_R(E_F)$ on the Fermi level at low temperatures of $T < T_K$. At high temperatures of $T >> T_K$, the Kondo fluctuations in spin are ineffective and the resonance is washed out.

Thus, two characteristic temperature modes must be differentiated in the behavior of a magnetic impurity in normal metal (Kondo problem). At high temperatures, $T > T_K$, the impurity is magnetic and the resonance is absent; at low temperatures of $T \lesssim T_K$, the impurity is nonmagnetic and an Abrikosov-Sul resonance forms on the Fermi level. The very decrease in the temperature itself caused a peculiar change in mode from a weak interaction of the impurity spin with the Fermi electrons at high temperatures to their strong bond at low temperatures where the Fermi electron becomes a "heavy fermion" on account of a constant exchange of spins with an electron of the deep f-shell.

The change in mode in the Kondo problem has also made a theoretical examination of the question difficult inasmuch as it has not been possible to find a perturbation applicable throughout the entire temperature interval. And only in 1980 did the Soviet physicist P.B. Bigman and later the American physicist N. Andrey construct an exact solution of Kondo's problem and compute unified temperature dependences for heat capacity and magnetic receptivity in a wide temperature range. The Bigman-Andrey solution yields $\gamma(T \to 0) \sim 1/T_K$, i.e., in effect, the amplitude of the Abrikosov-Sul resonance $g_{1R}(E_F)$ for one Kondo impurity inasmuch as $\gamma \sim g(E_F)$ (1).

From Kondo impurity to Kondo lattice. In the preceding section we explained that adding one Kondo impurity to normal metal results in the formation of a narrow peak on the Fermi level. Although this peak is very "sharp", its width is determined by the Kondo temperature; nevertheless, the peaks' amplitude for one impurity is certainly many times less than the nonperturbed density of the states $g_0(E_F)$ of normal metal: $g_{1R}(E_F) << g_0(E_F)$. And what will happen if we take not one but N_i Kondo impurities and attempt to attain an instance of rather large concentrations of N_i? For a weak interaction of Kondo impurities with one another, we nevertheless increase the amplitude of the Abrikosov-Sul resonance N_i times as much, and, in principle, we can obtain an inverse correlation $N_i g_{1R}(E_F) >> g_0(E_F)$ if we make N_i sufficiently large all the way up to N_A, where N_A is Avagadro's number. However, in the process we must somehow suppress the interaction of Kondo impurities with each other.

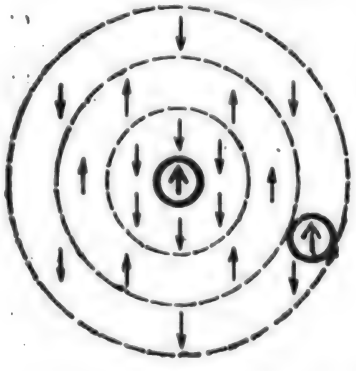


Figure 11. Superexchange interaction of localized spins (thick arrows) through oscillations in the electron spin density (alternating spherical layers with an identical orientation in electron spin)

In order to avoid the direct overlapping of deep electron shells bearing a noncompensated spin, it is necessary to take those magnetic ions with a small

shell radius when selecting ions to serve as Kondo impurities. The rare earth elements (Ce, Pr, Eu, etc.) and actinides (U, Np, Pu, etc.), whose f-shells have a radius of 0.3 Å, are well suited for this purpose. For such Kondo impurities, a direct overlapping of the f-shells will even be absent in the concentrated limit where the magnetic ion is aranged in each elemental cell and, consequently, $N_i = N_A$.

The second difficulty, which arises with an increase in N_i, is the indirect magnetic interaction of the Kondo impurities with one another. If, as a result of this interaction, the impurity spins "couple" and there is a transition to a magnetic state, then in the process the "electron magnetics" freeze in and are unable to complete a Kondo spin fluctuation.

As was mentioned previously, a superexchange interaction arises through an exchange of the free collectivized electrons of the conduction band. We will assume that for a single Kondo impurity the sign of the exchange interaction between the impurity spin and the spin of the Fermi electrons is such that these spins tend to be oriented in an antiparallel manner. Then a cloud of Fermi electrons with a counterspin forms around the impurity spin, and this cloud even overcompensates the impurity spin. Therefore, electrons with another spin direction accumulate in the next spherical layer, etc. (Figure 11). As a result, we have a system of spherical layers in which the spins are oriented in alternating sequence around the impurity layer.

If two magnetic impurities are imbedded, then the second of them, having ended up in one spherical layer or another, will tend to orient its spin in a manner that has already been completely determined (see Figure 11). This interaction of impurity spins with each other through oscillations (variable sign alternation) in the spin density of the conduction electrons is called a type Ruderman-Kittel-Kasuyn-Iosida [RKKI] superexchange interaction. Its intensity may be characterized by the introduction of a temperature T_{RKKI}, which depends on the width of the valence band $W \sim E_F$, and the constants of the exchange interaction I may be characterized in the following manner:

$$T_{RKKI} \sim I^2/E_F \tag{3}$$

Thus, if we have two Kondo impurities immersed in a "sea" of collectivized electrons, then we must examine two concurrent processes: 1) local Kondo fluctuations in spin that tend to attain an equally probable occupation of the "$\uparrow$" and "$\downarrow$" states corresponding to the nonmagnetic state of the impurity and 2) intercenter superexchange interaction for which a tendency toward magnetic ordering and freezing of the impurity spins in some kind of single fixed orientation, either "$\uparrow$" or "$\downarrow$", is characteristic. The effectiveness of the first process is estimated by the Kondo temperature T_K (2), which is exponentially dependent on the parameter of the exchange interaction I while the temperature T_{RKKI} is characteristic for the tendency to magnetic ordering and depends on I according to the quadratic law (3) (Figure 12).

If the value of the modulus I is small (less than $|I_c|$), then the quadratic dependence of T_{RKKI} (I) "overtakes" the exponential T_K (I), and with a decrease in temperature, we initially obtain a magnetic ordering of the impurities that

"forbids" local Kondo fluctuations in spin upon a further decrease in temperature inasmuch as the impurity spins are already "frozen out." With large $|I|$, there is an inverse correlation: $T_{RKKI} \ll T_K$, and with a decrease in temperature there is initially a complete Kondo compensation of the impurity spin. These compensated impurity spins, which are lower in temperature, are already unable to "couple" with one another through the mechanism of superexchange interaction.

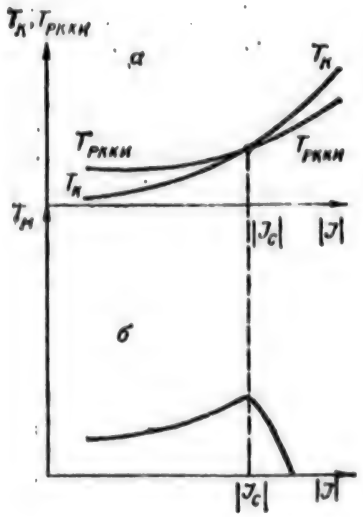


Figure 12. Concurrence of superexchange and Kondo exchange interactions: a, dependence of Kondo temperature (T_K) and temperature of the Ruderman-Kittel-Kasuin-Iosida superexchange interaction (T_{RKKI}) on the parameter of the exchange interaction I; b, dependence of temperature of the magnetic transition T_m on the parameter of I

Thus, for large $|I|$ the tendency toward a nonmagnetic Kondo state dominates over the tendency toward magnetic ordering of the impurity spins. In this case, even in concentrated Kondo systems in which there is a Kondo impurity in every elementary cell of the crystal, the indirect magnetic interaction of these "impurities" with one another is suppressed and, consequently, each Kondo center makes its own contribution to the formation of an Abrikosov-Sul resonance on the Fermi level. In the initial approximation, such concentrated Kondo systems may be viewed as N_j systems that are independent of the Kondo centers. Concentrated Kondo systems with $T_K \gg T_{RKKI}$ and periodically arranged Kondo centers are also called nonmagnetic Kondo lattices. In such lattices, the number of Kondo impurities in one mole is equal to Avogadro's number $N_A = 6.02 \times 10^{23}$; therefore, compared with the case of a single impurity, the amplitude of the Abrikosov-Sul resonance increases more than 10^{23} times as much.

As a result of this, a narrow peak of the giant amplitude, which exceeds the value of the density of the states on the Fermi level 100 to 1,000 times as much in normal metals such as Cu, K, Na, Ag, etc., forms in the nonmagnetic Kondo lattices on the Fermi level at low temperatures.

Thus, in nonmagnetic Kondo lattices, the superexchange interaction of the Kondo centers is suppressed, and in addition, there are many of these centers, one each in each elementary cell. It is precisely for this reason that a peak of the giant amplitude, which corresponds to "heavy fermions," Fermi electrons with an effective mass of $(10^2\text{-}10^3)m_0$, forms in such compounds on the Fermi level. The presence of a giant Abrikosov-Sul resonance on the Fermi level (as

was first shown by one of the authors, V.M.) leads to a change in all the low-temperature properties of the nonmagnetic Kondo lattices. All the parameters of such metals that are connected with the density of the electron states on the Fermi level (electron heat capacity, Pauli magnetic receptivity, effective mass, thermoelectromotive force coefficient, Fermi speed [see Table 1], etc.) differ from the corresponding values in normal metals 100 to 1,000 times as much. With respect to the set of anomalous low-temperature properties, Kondo lattices form a virtually new class of metal systems that are characterized by the presence of a very narrow peak in the giant amplitude on the Fermi level.

Superconductive Kondo lattices. The low-temperature properties of nonmagnetic Kondo lattices are so unusual that studying these systems in and of themselves is of great interest. However, this interest is even more intensified because several of the nonmagnetic Kondo lattices are superconductors since superconductivity is related to precisely the heavy fermions, i.e., to the electrons corresponding to the Abrikosov-Sul resonance.

The superconductivity of heavy fermions was first discovered in the compound $CeCu_2Si_2$ by F. Shteglikh in 1979. The presence of a magnetic, but not superconductive transition may most likely be expected in this compound. Therefore, when F. Shteglikh first discovered superconductivity in $CeCu_2Si_2$, several scholars felt that it is not this compound itself that superconducts, but rather its "dirt" impurities of other compounds, which, passing into a superconductive state, shunt the specimen. However, the change in heat capacity during the transition through T_c showed that the transition to a superconductive state is accompanied by a jump in heat capacity C since the magnitude of the jump ΔC $(T = T_c)$ was comparable with the most giant value of the low-temperature electron heat capacity above T_c.

This circumstance proves that, first, it is really the compound $CeCu_2Si_2$ itself that superconducts rather than the impurities contained in it, and second, that the superconductivity is related to the heavy fermions.

After looking at Table 1, it is easy to become convinced of the unusualness of the low-temperature properties of the nonmagnetic Kondo lattices in the normal state. Superconductive Kondo lattices in the superconductive phase (Table 2) possess no fewer exotic properties. Their characteristics are from 100 to 1,000 times different than the corresponding characteristics of normal superconductors, for example Sn.

Table 2. Characteristics of Superconductive Systems With Heavy Fermions Compared With a "Normal" Sn Superconductor

Сверхпроводник (1)	T_c, K	$H_{c2}(0)$, кЭ	$\frac{H_{c2}(0)}{T_c(0)}$, кЭ/K (2)	$\frac{dH_{c2}}{dT_c}$, кЭ/K	$\gamma(T\to 0)$, мДж/моль·K² (3)
$CeCu_2Si_2$	0,5	18	36	200	1050
UBe_{13}	0,85	130	150	270	1100
UPt_3	0,54	16	32	63	450
Sn	3,73	0,3	0,08	0,14	1,78

Key:

1. Superconductor
2. keV/degrees Kelvin
3. mJ/mol x K^2

First we will examine the behavior of superconductors with heavy fermions in a strongly magnetic field. All these compounds are type II superconductors. Inasmuch as the value of the critical temperature of superconductors with heavy fermions is not great (see Table 2) (it lies in the 0.5 to 0.9 K range), based on data known for normal superconductors, it would be possible to expect that a field of not more than 16 keV would be sufficient to suppress their superconductivity. In fact, if the electrons form a Cooper pair, the energy gain is $k_V T_c$. In the magnetic field H, besides this energy gain, it is necessary to make an allowance for the destructive effect of a magnetic field with a characteristic energy $\mu_V H$ on the superconductivity. The superconductivity is destroyed when the parallel orientation of the spins of the electrons forming the Cooper pair is more favorable: $\mu_V H \geq k_V T_c$. From this inequality it follows that the ratio $H_c(0)/T_c(0)$ is determined only by the universal constants k_V and μ_V, and therefore they should not depend on the type of superconductor. Thus, for T_c = 1 K, the limit field $H_c(0)$, the paramagnetic limit, is 16 keV.

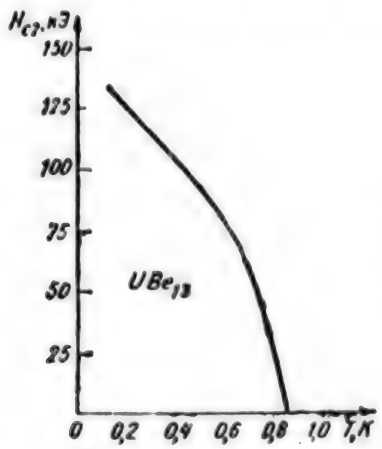


Figure 13. Dependence of the upper critical field H_{c2} on the temperature of the superconductor with heavy fermions UBe_{13}

Existing experimental data confirm that for superconductivity based on heavy fermions, a twofold increase in the paramagnetic limit is characteristic in $CeCu_2Si_2$ and more than a sixfold increase in UBe_{13}! It is not enough that in systems with heavy fermions, superconductivity arises under conditions in which it would be natural to expect a magnetic transition, so it is not so easy for superconductivity to be destroyed by a magnetic field!

In type II superconductors, the critical field curve $H_{c2}(T)$ (Figure 13) makes it possible to estimate the effective mass of the electrons m* forming the superconductive pairs. The point is that the slope of $H_{c2}(T)$ close to T_c is proportional to m*. Therefore, the giant value of the tangent of this slope (see Figure 13) as well as the magnitude of the jump in heat capacity at the moment of the superconductivity transition proves that it is heavy fermions that superconduct in $CeCu_2Si_2$, UBe_{13}, and UPt_3.

In addition to the record values of the product of the upper critical field (see Table 2) and the ratio $H_{c2}(0)/T_c(0)$, the very form of the curve H_{c2} (T) (see Figure 13) is also rather unusual. Saturation is characteristic in all normal superconductors in which the electrons forming the Cooper pair have opposite spins for the $H_{c2}(T)$ curves; when T = 0, their slope relative to the abscissa equals zero. In superconductors with heavy fermions, especially in

UPt_3 and UBe_{13}, the tendency toward saturation of H_{c2} when $T \to 0$ is virtually absent. One possible explanation for such behavior is the parallel orientation of the spins of the electrons in the pair when the total spin equals unity ("triplet superconductivity").

We will remember that in all presently known superconductors, the total spin of the pair equals zero ("singlet superconductivity"). Thus, superconductors with heavy fermions are the first compounds in which the possibility of triplet coupling is allowed and considered. From this point of view, the absence of $H_{c2}(T)$ saturation when $T \to 0$ is related to the fact that during a parallel orientation of the spins the destructive effect of the magnetic field on the superconductivity is negligibly small in relation to the case of oppositely directed spins in the pair.

It should be noted that triplet coupling of fermions really does exist. However, until now, its existence has only been proved with certainty in the case of superconductive ^3He, in which the superfluidity at very low temperatures, $\sim 10^{-3}$ K, is related with the Bose-condensation of the pairs possessing a parallel orientation of their spins. There is a deep analogy between the superfluidity of ^3He and superconductivity in the system of heavy fermions with respect to a number of properties (see later sections of this article). Thus, in the study of superconductors with heavy fermions there is a linking of such diverse areas of low-temperature physics as the physics of quantum liquids and the physics of metals.

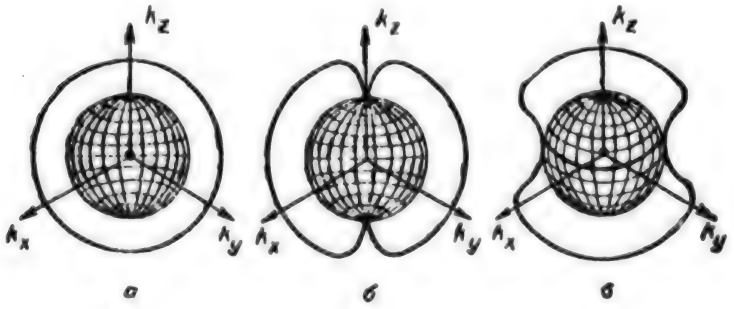


Figure 14. Schematic depiction in a pulsed space of a superconductive slot $\Delta(k)$ in an ordinary superconductor (a) and the possibility of its going to zero at the poles (b) or along the equator (c) in superconductors with heavy fermions

An energy slot Δ, which separates the levels of the Bose-condensate of the Cooper pairs from the closest permitted single-electron levels (see Figure 1), forms on the Fermi level during a superconductive transition. In normal superconductors, the slot is identical for all directions of the quasipulse k (Figure 14a); therefore, when there is a decrease in temperature in the $T \lesssim T_c$ range, the number of unpaired electrons excited through the slot diminishes exponentially with the temperature, and all the electron characteristics, such as electron heat capacity C, spin-lattice relaxation time τ, coefficient of the absorption of sound by electrons α, etc., are also exponentially dependent upon temperature.

For superconductors with heavy fermions, gradual dependencies of C, τ, and α are observed instead of exponential dependencies. Thus, in the superconductive phase in the compound UBe_{13}, $C \sim T^3$, whereas in $CeCu_2Si_2$, $C \sim T^2$. The law $C(T) \sim T^3$ indicates the possibility of the superconductive slot going to zero at discrete points, on the poles (see Figure 14b), and the dependence $C \sim T^2$ is characteristic for going to zero Δ along the line (along the equator) (Figure 14c).

One possible explanation for the sharp anisotropy of the slot $\Delta(k)$ is based on the hypothesis of the existence of triplet superconductivity in superconductors with heavy fermions. However, as in the case of critical field curves (see Figure 13), the graduated dependencies of C, α, and τ on temperature are not unequivocal proof of triplet superconductivity inasmuch as an alternative interpretation of the anisotropy of $\Delta(k)$ is possible. Thus, at present there is no unequivocal answer to the question of the nature of the superconductivity of heavy fermions.

As far as the heaviest fermions in $CeCu_2Si_2$, UBe_{13}, and UPt_3 are concerned, the heavy fermions in the first two compounds most likely occur as a consequence of the Kondo fluctuations in spin. In other words, the heavy fermions in the superconductive Kondo lattices of $CeCu_2Si_2$ and UBe_{13} are electrons corresponding to a very narrow Abrikosov-Sul resonance of the giant amplitude. With respect to its properties, the compound UPt_3 differs significantly from the superconductive Kondo lattices, and it is still unclear where the heavy fermions in this compound come from.

The presence of a very narrow peak in the density of the states on the Fermi level in $CeCu_2Si_2$ and UBe_{13} leads to a strong dependence of the superconductivity properties of these compounds on the introduction of various impurities, both magnetic and nonmagnetic. It is known that in ordinary superconductors magnetic impurities suppress superconductivity, whereas nonmagnetic impurities have a very weak effect on the temperature of a superconductive transition. In superconductive systems with heavy fermions, nonmagnetic impurities, as well as magnetic, have a strong effect on superconductivity properties.

Thus, in $CeCu_2Si_2$ and UBe_{13} it is sufficient to add 1% to 2% nonmagnetic LaTh ions, etc., instead of the Ce and U ions as the temperature of the superconductivity transition decreases sharply to values of $T_c < 0.07$ K. Comparing, for example, the compound $CeCu_2Si_2$ (superconductor, $T_c \simeq 0.5$ K) with its nonmagnetic analogue $LaCu_2Si_2$ (normal nonsuperconductive metal all the way up until 0.012 K) and considering that replacing Ce by La leads to a sharp decrease in T_c, we come to the following conclusion: in $Ce_xLa_{1-x}Cu_2Si_2$, the greater the concentration of Ce^{3+} magnetic ions, the higher the T_c. This result has a fundamental significance for discovering an interconnection between superconductivity and magnetism.

Yet another interesting effect related to the interaction of Kondo compensation of magnetic moment on the one hand and to the tendency toward establishment of superconductivity on the other was discovered by K. Vintser and R. Krug in the compound $Ce\ La_{1-x-y}Y_y$. If an ordinary superconductor is characterized by the presence of one critical temperature T_c and reversible superconductivity with two temperatures (see Figure 6), T_c and T_{c2}, is possible in magnetic superconductors, then three critical temperatures, $T_c > T_{c2} > T_{c3}$, were discovered in the specified compound. It turned out that this became possible because of the fulfillment of a specified correlation between the Kondo temperature T_K and the temperatures T_c and T_{c3}: $T_c >> T_K >> T_{c3}$. During the first superconductivity transition $T = T_c$, the magnetic impurities still exert a weak effect on the superconductivity as a result of the condition $T_K << T_c$. Then, decreasing the temperature, we reach the temperature range $T \sim T_K \sim T_{c2}$, where Kondo processes with a spin flip that destroys the Cooper pairs, which results

in a restoration at $T = T_{c2}$ of the normal superconductive state, are very effective. If the temperature is reduced further such that the condition $T \ll T_K$ is fulfilled, then the completely screened (on account of the Kondo effect) magnetic ions do not hinder the recurrent establishment of superconductivity when $T \leq T_{c3}$. Thus, we encounter a situation where there are two superconductive transitions, when $T = T_c$ and $T = T_{c3}$, and an intermediate region of the normal phase, when $T_{c3} \leq T \leq T_{c2}$.

In concluding this section, it should be noted that the main feature of superconductive systems with heavy fermions is the presence in the vicinity of the Fermi level of a very narrow peak in the density of the states to which the heavy fermions, quasiparticles with a high effective mass, correspond. These systems possess an entire series of anomalous properties both in the normal and superconductive phases. Studying heavy fermions in metals has significantly expanded our ideas about superconductivity and magnetism, which were previously interpreted as completely antagonistic phenomena. On the example of "exotic" superconductors and superconductivity systems with heavy fermions in particular, it is well seen that this is not so. Thus, the discovery and investigation of new superconductive materials, "exotic superconductors," have served as a powerful stimulus for the further study of such amazing phenomena as superconductivity and magnetism.

IV. Organic Superconductors

The colossal success of organic chemistry has resulted in our living in an environment of very diverse synthetic organic materials. The broad spectrum of the use of organic compounds and the continual purposeful synthesis of newer and newer compounds with amazing characteristics attests to the possibility of creating organic material possessing virtually any specified physical properties in advance. The discovery of organic conductors and later superconductors is additional affirmation of this. It should also be mentioned that the discovery of organic superconductivity was not a result random searches, it was the successful completion of purposeful searches lasting more than 15 years. Researchers had to overcome many difficulties on this path; in essence, a new area of solid-state physics was created, the physics of synthetic metals.

Exciton mechanism of superconductivity. V. Little's idea about the possibility of the occurrence in organic systems of a unidimensional type of high-temperature superconductivity, which he spoke of in 1964, provided the beginning of intensive searches for organic superconductors. Here, the mechanism of the formation of Cooper pairs is not connected with the deformation of the lattice (i.e., with the phonons) as in ordinary superconductors, but with the electron polarization of side organic molecules.

Little's idea consisted of the following. We will examine a certain hypothetical substance in which a framework of hydrocarbon atoms creates a unidimensional conduction path and large organic hydrocarbon molecules (for this purpose, Little proposed using dyes) are arranged along the sides of the framework. If the organic molecules contain valence electrons that move freely throughout the molecule, then they should be easily polarized. An electron moving along the hydrocarbon framework will repel the valence electrons of the hydrocarbon molecules. As a result, an excess positive charge will appear on the parts of

the organic molecules that are closest to the framework. A second electron may be attracted to this positive charge, which leads to the appearance of an effective attraction between the electrons and to the formation of Cooper pairs.

Thus, unlike the ordinary phonon mechanism where the attraction of the electrons is caused by the occurrence of a positive charge on account of the displacements of the ions, in Little's model it appears thanks to the displacement of the valence electrons in the hydrocarbon molecules.

Such a formation mechanism of the Cooper pairs in exciton superconductors may be expected based on the following considerations. In ordinary superconductors, as was mentioned in Section 1, the critical temperature is inversely proportional to the square root of the ion mass in the metal's lattice. Inasmuch as the exciton attraction mechanism is connected with the displacement in the side organic molecules of the electrons, whose mass is approximately 10^5 times less than the mass of typical metal ions, then based on a crude estimate, an increase 100 times as much should occur in the critical temperature!

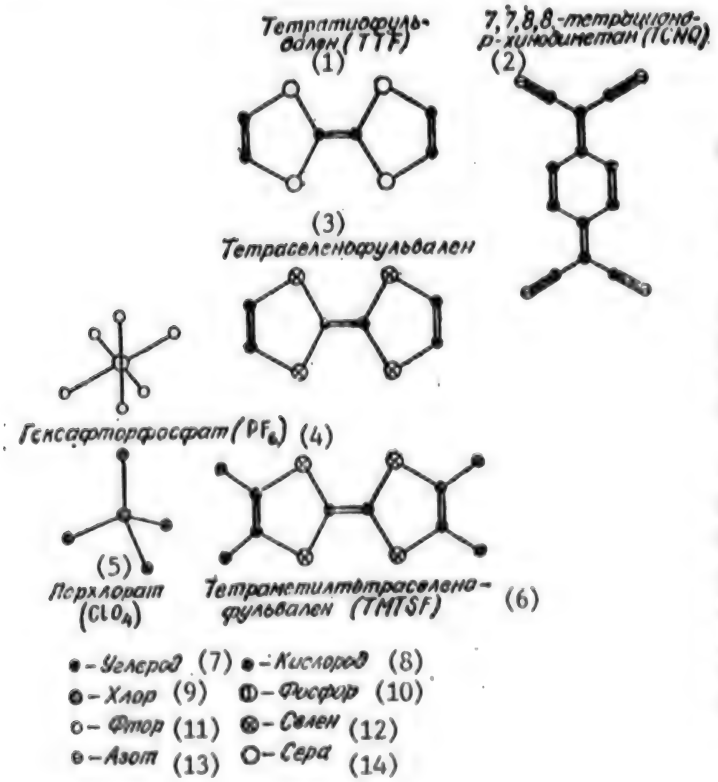
Also in 1964, when Little proposed beginning a search for organic superconductors, V.L. Ginzburg advanced the idea of the possibility of implementing the exciton mechanism of high-temperature superconductivity close to a metal-dielectric (or semiconductor) interface in multilayered films. All of this caused exceptionally great interest in searching for exciton superconductors among quasiunidimensional and two-dimensional compounds. A large number of new interesting materials were created and studied; however, in all superconductors obtained up until now (including organic superconductors), Cooper coupling occurs as a result of the normal phonon mechanisms. The question of the possibility of high-temperature superconductivity based on an exciton mechanism still remains open.

Organic conductors. The hypothesis of high-temperature organic superconductivity has provided a high impetus for investigations of synthetic materials. However, the majority of organic synthetic materials are insulators, and thus the search for organic metals in and of itself has been a very complicated problem. Obtaining good, technologically feasible, and inexpensive organic materials is also important from the point of view of searching for a replacement for the traditional electrical engineering material, copper, deposits of which will be almost completely exhausted by the end of the 20th century (at room temperature the conduction of copper attains a value of 10^5 ohms^{-1} x cm^{-1}).

Until now, all good organic metals have been obtained on the basis of one-dimensional molecules with frightening long names that are composed of atoms of carbon and hydrogen with the addition of such atoms as nitrogen, sulfur, and selenium. Figure 15 presents the more typcial "building blocks" of organic metals. The valence electrons of the molecule are localized above and below its plane. In a crystal, these molecules are packed in the form of stacks. A good overlapping of electron wave functions along the stacks provides a high conduction in this direction. At the same time, the electrons virtually do not pass from one stack to another. As a result, organic metals are characterized by the appearance of strong anisotropy, and conduction along the stacks significantly (1,000-fold in the series of compounds) exceeds conduction in the

perpendicular direction. In fact, such sythetic metal is a quasiunidimensional conductor based on its electron properties. As a rule, the crystal consists of donor and acceptor molecules that form oppositely charged stacks, and stacks of both types of molecules as well as stacks of only one type may have good conduction.

Figure 15. Structural blocks of quasiunidimensional organic conductors (as well as superconductors)



Key:

1. Tetrathiofulvalene [TTF]
2. 7,7,8,8-Tetracyano-p-quinodimethane [TCNQ]
3. Tetraselenofulvalene
4. Hexafluorphosphate (PF_6)
5. Perchlorate (ClO_4)
6. Tetramethyltetraselenofulvalene (TMTSF)
7. Carbon
8. Oxygen
9. Chlorine
10. Phosphorus
11. Fluorine
12. Selenium
13. Nitrogen
14. Sulfur

Tetrathiofulvalene-tetracyuanoquinodimethane [TTF-TCNQ] is a typical and much-studied representative of the class of organic metals. In the crystal of this substance planar molecules of TTF and TCNQ are packed in separate stacks, and on average 0.59 electrons pass from the donor stacks of TTF to the acceptor stacks of TCNQ in computation for one molecule. As a result, the electron bands of both types of chains are only partially occupied, and the possibility of the motion of the electrons along these chains arises; for chains of TCNQ this will be electron-type conduction, and for TTF chains, hole-type. The conduction of this compound grows strongly with a decrease in temperature, and at 60 K it becomes comparable with the conduction of copper at room temperature; however, a further decrease in temperature leads to a sharp fall in conduction and to a transition to the dielectric phase.

Up until now, a large number of organic metals have been obtained; however, as of yet they have surely been unable to compete with traditional conductors because of the complexity of their synthesis and because of their low technological feasibility. It would be very tempting to create an organic polymer metal, and in the future, a superconductive polymer.

At present, only one inorganic superconductive polymer, polysulfurnitride $(SN)_x$, is known. This compound was synthesized rather long ago, in 1910; however, its superconductivity was only discovered in the beginning of the seventies, and its critical temperature was very low, 0.3 K. The polymer $(SN)_x$ consists of SN chains. A strong overlapping of wave functions along the chains ensures the high conduction of polysulfurnitride in this direction (2×10^3 ohms^{-1} x cm^{-1} at room temperature). Conduction is also great in the direction perpendicular to the chains.

In fact, based on its electron properties, this polymer is not quasiunidimensional, but an anisotropic three-dimensional compound. The entire complex of experimental data confirms that the usual phonon mechanism is responsible for the superconductivity in polysulfurnitride, and its superconductive properties are well described by the BKSh theory [not identified further].

Dielectric Peierls transition. As has already been mentioned, at low temperatures, there is a sharp drop in conduction in the compound TTF-TCNQ, and the crystal loses its metallic properties. Analogous behavior has been discovered in many other quasiunidimensional organic conductors. This phenomenon, which researchers have encountered on the way toward creating an organic superconductor, is an important characteristic feature of unidimensional systems. The instability of the metallic state in unidimensional systems at low temperatures was first predicted in 1953 in the theory of R. Peierls. At the time, it appeared that this prediction had only academic interest. However, with the apearance of quasiunidimensional organic metals, Peierls's hypothesis was completely confirmed experimentally, and the corresponding transition to the dielectric phase received the name Peierls transition.

What is the physical essence of a Peierls transition? For an example, we will examine a homogeneous chain of molecules in which the strong overlapping of valence electron wave functions (orbitals) results in metallic conduction along the chain. If one valence electron occurs in each molecule, then the conduction band (allowing for the electron spin) is half occupied. In the given case, this means that all the electron states with a wave vector, $k_F < k < k_F$, where the wave vector k_F corresponds to the Fermi pulse p_F and is equal to $k_F = \pi/2a$ (half the maximal possible wave vector of the electron), will be occupied.

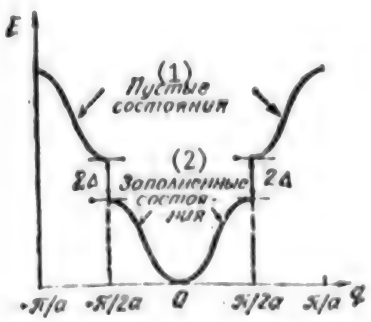


Figure 16. Doubling of the period in a half-filled electron band leads to the appearance of a slot on the Fermi surface; as a result the metal is transformed into a dielectric.

Key:

1. Empty states
2. Occupied states

As a result of the paired convergence of the molecules (Figure 16), the period of the chain under examination doubles, and an energy slot 2Δ, which is proportional to the displacement of the molecules, appears on the Fermi surface (when $k = \pm k_F$) in such a new chain. The doubling of the period corresponds to the

occurrence of a supplementary potential that acts on the electrons with a period 2a,i.e., to the wave vector $2\pi/2a = \pi/a = 2k_F$. This potential results in the strong interaction of the electron states with the wave vectors close to +k and -k .

As a result of the rearrangement of the electron states, the valence energy band splits in two: the lower part is completely occupied and the upper part is empty. The energy of the electron states is reduced in the process, and the complete reduction in electron energy is proportional to the value $\Delta^2 \ln \Delta$. At the same time, the increase in lattice energy on account of the appearance of a deformation wave with the wave vector $2k_F$ is proportional to the square of the displacement, i.e., Δ^2. The presence of a logarithmic factor in the change in electron energy shows that with low deformations the reduction in electron energy is greater than the growth in lattice energy.

Thus, the doubling of the period reduces the complete energy of the system, and the homogeneous state of the chain is unstable at zero temperature. In other words, when the temperature is reduced, the homogeneous state at a certain temperature T_P , the Peierls transition temperature, is transformed into a heterogeneous state. Inasmuch as a slot appears on the Fermi surface in the electron spectrum in the process, the conduction may be provided only by the thermal excitation of the electrons through this slot, i.e., the Peierls transition results in the transformation of a unidimensional metal to a semiconductor or dielectric. Typical values for the Peierls transition temperature lie in the 10 to 100 K range.

The wave vector of the dispacements of the molecules during a Peierls transition equals $2k_F$ and correponds to the doubling only during a half occupation of the original energy band. In the general case, the period of the displacements is incommensurate with the period of the original chain. Thus, in TTF-TCNQ the electron band is somewhat less than one-third occupied. The Peierls transition is registered well both by a fall in conduction and by the appearance of displacements of the molecules that are fixed by methods of x-ray structural analysis.

The appearance of ion displacements during a Peierls transition is accompanied by a redistribution of electron density; it increases in regions of an excess positive charge. This change in electron density bears the name charge density wave. The motion of such a wave as a unified whole results in the occurrence of a new conduction mechanism. It was first noted by G. Frohlich. It is important that the motion of a charge density wave is a collective effect. All the electrons participate (the ion change does not move as a whole in the process, but the ions make an oscillating motion). The presence of an energy slot in the electron spectrum stabilizes this motion: the electron is "frozen into" the charge density wave, and the dispersion on the impurities should not break down the current state.

All of this is analogous to the situation in superconductors, and it is curious that in his original work Frohlich proposed using the idea of the motion of a charge density wave to explain the phenomenon of superconductivity. The superconductivity seemed different; however, the idea "worked" on quasiunidimensional metals. The Frohlich conduction mechanism is implemented in a peculiar fluctuation mode in TTF-TCNQ; it explains the sharp growth in conduction upon a

decrease in temperature around T_p. Below the Peierls transition temperature, effects of the coupling (pinning) of the charge wave beyond the impurities and structural defects begin to be felt, which results in the "offswitching" of the Frohlich mechanism, and the compound becomes a Peierls dielectric. The commensurability of the period of this wave with the period of the original chain also results in the pinning of the charge density wave.

An external electrical field acts on the charge density wave, trying to shift it. When the field attains a certain threshold value, a separation of the wave occurs, and the Frohlich conduction mechanism is activated. As a result, the conduction of a Peierls semiconductor or dielectric is strongly nonlinear, depending on the applied field. The motion of the electron spin density wave may also be accompanied by the generation of an alternating electric current. All of these unusual properties of Peierls dielectrics are caused by the collective nature of the conduction mechanism and do not have analogues in ordinary metals.

It should be noted that polyacetylene $(CH)_x$, by which the doubling of the period of the chain $(CN)_x$ takes place (for polyacetylene, the Peierls transition temperature is higher than the temperature of its chemical decomposition, i.e., it is always located in a Peierls dielectric state), has attracted particular attention.

The amazing properties of polyacetylene deserve their own story. Here we will mention only that in this compound the transfer of current and magnetic moment (spin) by solitons, solitary nonlinear waves, is possible. Thus, the search for organic superconductors resulted in the discovery of a whole new class of compounds with amazing properties that are now studied intensively and have great interest by themselves.

Synthesis of the first organic superconductors. When the instability of unidimensional organic superconductors in relation to a dielectric Peierls transition was discovered, the efforts of researchers working on obtaining organic superconductors were directed toward eliminating this transition. Inasmuch as an exchange between neighboring stacks of molecules always takes place in real organic crystals, it is only possible to consider them approximately unidimensional. The intensification of the interaction between the chains makes the crystal more three dimensional, and in the process the Peierls transition must finally disappear becuase it is inherent to unidimensional systems.

In particular, applying external high pressure reduces the distance between the chains and may thereby suppress the Peierls transition. It is interesting that, as follows from the theory, in general, phase transition, including a superconductive transition, can take place in a purely unidimensional system; strong fluctuations destroy it. However, interactions between the chains in real compounds attenuate the fluctuations and in practice remove this prohibition.

Investigations of organic metals under pressure that were conducted by the French group Jerome played an important role in the search for organic superconductors: using pressure, it was possible to stabilize the metal phase in the compound TMTSF-DMTCNQ. When cooled, this compound does not pass into a dielectric phase but remains a good conductor at helium temperatures as well. Its conduction at low temperatures and a pressure of 10 kb is 10 times greater than the maximal conduction of TTF-TCNQ.

Comprehensive investigations of TMTSF-DMTCNQ showed that the high conduction of the material is caused mainly by stacks of molecules of TMTSF cations. This fact caused the Danish chemist K. Bechgord to synthesize an entire series of highly pure compounds in which the properties of these two molecules were intensified.

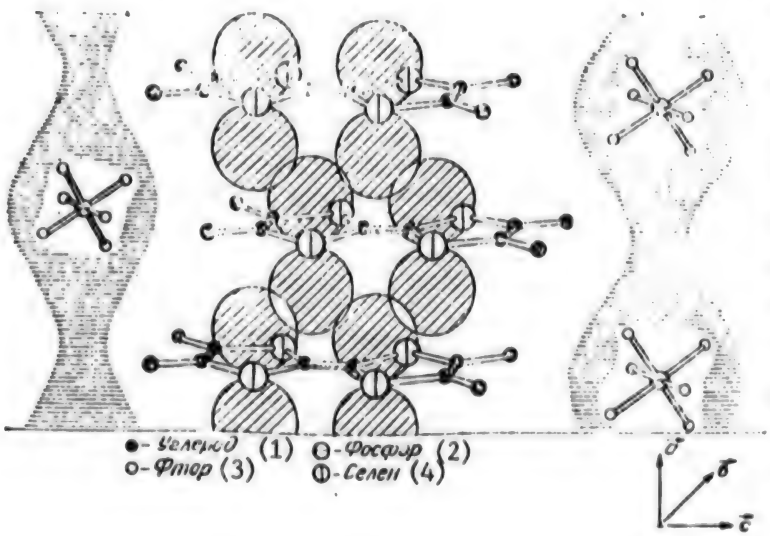


Figure 17. Schematic form of the crystalline structure of an organic superconductor $(TMTSF)_2 PF_6$. The electron wave functions overlapping along the chains (axis a) are shown by diagonal hatching. The TMTSF and PF_6 chains form parallel layers alternating along the c axis (corresponding to the plane ab)

Key:

1. Carbon
2. Phosphorus
3. Fluorine
4. Selenium

Neutral molecules of TMTSF were dissolved in an organic solvent, and then salt was added, establishing negatively charged ions. Next platinum electrodes were immersed in the solution, and an electric current was passed through. The valence electrons of the TMTSF molecules passed to the positive electrode, and the positively charged molecule (cation) arising in the process entered into a chemical reaction with one negatively charged ion and the neutral TMTSF molecule. As a result, highly pure needle-shaped crystals of type $(TMTSF)_2X$ salts, where X designates a negatively charged ion such as PF^-_6, hexafluorphosphate, etc., grew at the positive electrode.

Measurements of the conduction of the $(TMTSF)_2PF_6$ (tetramethyl-tetraselenofulvalene-hexafluorphosphate) salt under a pressure of 12 kb that were made in December 1979 by the Jerome group detected a drop in resistance to zero at a temperature around 1 K. Magnetic measurements demonstrated the exclusion of the magnetic field from the specimen, which is an indirect manifestation of the Meisner effect. Thus the first organic superconductor was discovered.

The electron wave functions of planar TMTSF molecules in this compound overlap in the direction along the chains of the molecule, providing good conduction. Figure 17 provides a schematic representation of the structure of $(TMTSF)_2PF_6$. It appears as parallel layers of chains of TMTSF and PF_6 alternating along the c axis. The PF^-_6 anions do not participate directly in the conduction.

In crystals of $(TMTSF)_2PF_6$, superconductivity occurs only under a pressure above 10 kb. At normal atmospheric pressure, reducing the temperature causes a transition into a dielectric state. The temperature of this transition is T = 12 K, and as research has shown, it has nothing in common with the Peierls transition. External pressure suppresses the dielectic transition, and as a result, a metal phase lower that 1 K becomes a superconductor.

Beginning the study of the compound $(TMTSF)_2ClO_4$, researchers of the Jerome group suggested that replacing PF by an anion with a somewhat smaller size will in a certain sense be equivalent to compression by pressure. The idea of "chemical compression" was completely justified. The compound $(TMTSF)_2ClO_4$ was a superconductor[2] under normal atmospheric pressure with a critical temperature of $T_c = 1.3$ K. (Footnote 2) (The value of the critical temperature changes somewhat depending on the quality of the crystals as well as on the cooling rate of the specimen.) The structure of this salt is analogous to the structure of $(TMTSF)_2PF_6$, and such is the structure of compounds with AsF_6, SbF_6, TaF_6, and ReO_4 anions where the superconductive transition occurs under the effect of external pressure.

The unidimensional anisotropy of $(TMTSF)_2X$ salts is significantly less than in the typical quasiunidimensional compound TTF-TCNQ. The conduction in it is rather high not only along the TMTSF chains, but also along the layers (the ac plane) that form these chains. The axis with the worst conduction is the c axis, along which layers of anions and cations alternate. In fact, the layers are not quasiunidimensional but quasi-two-dimensional superconductors.

To date, detailed studies of the superconductive properties of $(TMTSF)_2ClO_4$ have been conducted (working with other salts of this class is less convenient inasmuch as the superconductivity in them occurs under pressure). The entire complex of experimental data confirms that the usual phonon mechanism of superconductivity is apparently implemented in these compounds.

Dielectric transition to a charge density wave state. Although there are no indications for the manifestation of the exciton mechanism of superconductivity in organic $(TMTSF)_2X$ superconductors, the given class of superconductors nevertheless possesses a number of unique features. Here again we encounter a rivalry between magnetism and superconductivity. The point is that the dielectric transition in these salts that occurs in the absence of external pressure, as has already been mentioned, is not related to Peierls instability. It has a different, magnetic nature. The most painstaking x-ray investigations have shown the absence of any displacements of atoms during this transition. At the same time, magnetic measurements have detected a significant change in the behavior of magnetic receptivity (the proportionality factor between the magnetic moment and the external field) below the transition temperature T_s: the paramagnetic receptivity becomes anisotropic and goes to zero along one direction when the temperature decreases to 0 K.

Such behavior is typical for antiferromagnetics, and the dielectric transition in $(TMTSF)_2X$ crystals is really an antiferromagnetic transition. However, inasmuch as there are no localized magnetic moments in these compounds, an antiferromagnetic ordering of the spins of the conduction electrons, the spin density wave, must appear. Like the charge density wave, it is characterized by a wave vector of $2k_F$, which results in the appearance of a slot on the Fermi surface and the dielectrization of the system.

The possibility of the occurrence of a charge density wave was first predicted by A. Overhauser. Generally speaking, a unidimensional system may be unstable with respect to the transition to both a charge wave and spin density state. $(TMTSF)_2X$ salts, however, were the first (and to date the only) quasiunidimensional compounds where a transition to a spin density wave state [VSP] is observed.

At normal pressure, the dielectic transition to a spin density wave excludes the manifestation of superconductivity. Pressure suppresses this transition (Figure 18), and near a pressure of 10 kb there is a region where superconductivity arises against the background of a spin density wave.

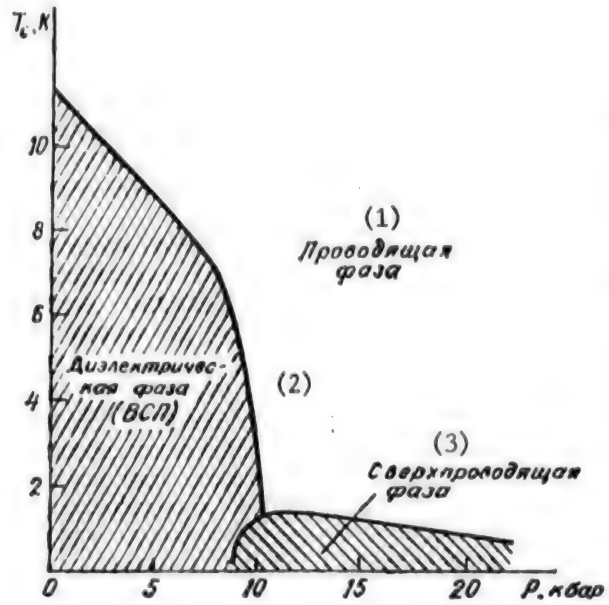


Figure 18. Phase diagram of the compound $(TMTSF)_2 AsF_6$ in "temperature-external pressure" variables (based on data of Brusetti et al, 1982)

Key:

1. Conductive phase
2. Dielectric phase [VSP]
3. Superconductive phase

The new organic superconductor $(BEDT\text{-}TTF)_2I_3$. The superconductivity in the family of organic compounds that have been discussed early in this work is characterized by a critical temperature of 1 to 1.3 K, which is very modest compared with traditional superconductors. However, in 1984 E.B. Yagubsk synthesized a new organic compound triodid-bis-ethylenedithilo-tetratulvalene, $(BEDT\text{-}TTF)_2 I_3$. Research conducted by I.F. Shchegolev's group discovered a superconductive transition in a number of crystals of this salt with $T_c \sim$ 6-8 K. Such a value for the critical temperature is currently the record for organic superconductors. The structure of $(BEDT\text{-}TTF)_2I_3$ crystals is close to the structure of $(TMTSF)_2X$ compounds, but are obtained in the form of wafers and are more quasiunidimensional. There are still no indications of an exotic nature of the superconductivity mechanism in $(BEDT\text{-}TTF)_2I_3$, and evidently it is the ordinary phonon mechanism.

Synthesizing organic superconductors is currently a very complex matter. However, the capabilities of organic chemistry make it possible to work with an enormously wide set of the most diverse compounds. It may be hoped that modern molecular engineering will make it possible to synthesize more technologically feasible organic superconductive materials possessing high critical temperatures, which are important from the point of view of practical applications.

Conclusion

The birth of exotic superconductors, which has been discussed in this paperback, occurred at the very end of the 1970s. They owe their creation to the impressive successes in the synthesis of new materials. Only a short time ago, few suspected the possibility of their existence. Now research on exotic superconductors is progressing at full steam. The prospects for the practical use of their amazing properties are very promising, and they await their embodiment in specific developments. From the point of view of fundamental

science, exotic superconductors have already provided much for low-temperature physics, in particular for explaining the connection between superconductivity and magnetism.

Superconductors with heavy fermions as well as magnetic and organic superconductors do not exhaust the list of exotic superconductors. The superconductivity of systems with strong structural disorder and superconductivity close to the twinning plane (the interface of two grown symmetrical monocrystals) have also recently aroused great interest. Disorder facilitates the localization of electrons in metals and may lead to a transition to a dielectric state.

In this context, the question of superconductivity under conditions of such dielectrization has become interesting. As far as the twinning plane is concerned, as the works of M.S. Khaykin and I.N. Khlyustikov have shown, its presence in tin, for example, eases the formation of Cooper pairs.

As a result, as the temperature decreases, superconductivity initially arises around the twinning plane, but not in the bulk of the specimen. Such a localized superconductivity is surrounded by normal metal, which strongly suppresses it. Having prepared very tiny specimens with twinning planes or having created a high concentration of such planes, it is possible to get rid of this effect. In this way, it has already been possible to increase the critical temperature of tin nearly three times as much!

In conclusion, it should be noted that exotic superconductors are in fact related to a new stage in the development of the physics of superconductivity.

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12794
CSO 1862/205

TECHNICAL PHYSICS

EXCITATION OF UPPER HYBRID RESONANCE IN IONOSPHERIC PLASMA BY POWERFUL RADIO WAVE FIELD

Moscow PISMA V ZHURNAL EKSPERIMENTALNOY I TEORETICHESKOY FIZIKI in Russian
Vol 43, No 11, 10 Jun 86 (manuscript received 18 Apr 86) pp 512-515

[Article by V.V. Vaskov, S.F. Golyan, A.V. Gurevich, Ya.S. Dimant, V.A. Zyuzin, V.Yu. Kim, G.P. Komrakov, L.A. Lobachevskiy, V.V. Migulin, N.A. Mityakov, V.A. Panchenko and V.P. Polimatidi, Scientific Research Radiophysics Institute, Ministry of Higher and Secondary Education RSFSR]

[Abstract] This article presents the first report of experimental detection of accumulation of slow wave energy, causing local anomalous adsorption of a powerful radio wave at heights of over 200 km in the ionosphere causing effective thermal and striction extrusion of the plasma from the upper hybrid resonance area. Experiments were performed in 1983-1985 during the day and evening under quiet geophysical conditions. The ionosphere was excited with waves of ordinary polarization at 4.785 MHz and 5.828 MHz with equivalent radiated power 150 Mw and 220 Mw. The experiment showed that at over 200 km altitude, the area of upper hybrid resonance of the powerful radio wave is sharply delineated. A figure illustrates the time course of Doppler displacement of the test frequency. The experimentally observed behavior of Doppler displacement of frequency and amplitude of the test waves at the upper hybrid resonance frequency agree with the predictions of the theory of local excitation of plasma turbulence in the small vicinity of the upper hybrid resonance of a powerful electromagnetic wave.
Figures 2, references 9: Russian.

6508/12379
CSO: 1862/243

ULTRASOUND ELECTROMAGNETIC ABSORPTION PEAKS IN REGION OF DOPPLER-SHIFT CYCLOTRON RESONANCE

Moscow ZHURNAL EKSPERIMENTALNOY I TEORETICHESKOY FIZIKI in Russian Vol 43, No 2, Jun 86 (manuscript received 4 Apr 86) pp 582-583

[Article by V.V. Gudkov and I.V. Zhevstovskikh, Institute of Chemical Physics, USSR Academy of Sciences]

[Abstract] The absorption of circularly polarized ultrasonic waves in tungsten in the G-Doppleron phonon resonance region is investigated experimentally. Besides the main maximum of the Doppleron-phonon resonance in the (-) polarization, additional maxima are observed in both polarization in the H_r^- and H_r^+ fields. The idiosyncrasies detected are explained within the framework of the phenomenological theory as the electromagnetic absorption peaks of ultrasound in the Doppler-shift cyclotron resonance region. The position of these peaks over the magnetic field can be used to recover the Hall component of the nonlocal conductivity tensor beyond the edge and in the region of cyclotron absorption, thus significantly expanding the capabilities of ultrasonic spectroscopy. Figures 2, references 5: 4 Russian, 1 Western.

6900/12379
CSO: 1862/251

NONSTEADY ACCELERATION OF IONS IN HIGH-CURRENT PLASMA OF MICROWAVE DISCHARGE

Leningrad PISMA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 11, No 24, 26 Dec 85 (manuscript received 6 Sep 85) pp 1491-1495

[Article by V.V. Alferov, I.P. Gladkovskiy, V.A. Ivanov, and A.L. Orbeli, Institute of General Physics, USSR Academy of Sciences, Moscow]

[Abstract] Acceleration of ions in a plasma generated by a microwave converter operating at high current levels was studied experimentally with an apparatus consisting of a vacuum chamber (10^{-3} Pa), a dielectric (plexiglass) plate with an electrode mounted at the center, an ion analyzer aimed at the target at a 22° angle to the impinging radiation beam, and a floating plasma probe with a high-resistance load of 10^4 ohms for scanning the electric field and measuring the potential distribution. Microwave radiation at the $\lambda = 16$ cm wavelength in pulses of 40 μs duration was beamed from the converter through a window in the chamber toward the electrode till ions together with electrons escaped from the coronating target plate after optical breakdown in an electric field of 1.7 kV/cm intensity, with the electrode connected to the chamber walls at ground potential through a load resistance of only 0.1 ohm and thus corresponding to nearly a short circuit. The envelope of microwave pulses, the potential at the electrode, the potential at the floating plasma probe, and the fluxes of 0.2-3 keV C^+-ions were recorded in time on oscillograms. The results of this

experiment suggest that with a microwave converter operating at a high current level the energy spectrum of ions emitted by a target is continuous over a wide range, even though the integral-over-time energy spectrum is essentially the same as when the microwave converter operates at a low current level and produces an ion energy spectrum which is discrete in time. Figures 3; references 7: all Russian.
[124-2415]
/12379

EXPLOSIVE MODES OF NON-ISOTHERMIC GROWTH OF SPHERICAL CENTER OF PHASE TRANSFORMATION DURING DECAY OF FROZEN METASTABLE STATES

Moscow ZHURNAL EKSPERIMENTALNOY I TEORETICHESKOY FIZIKI in Russian Vol 90, No 1, Jan 86 (manuscript received 27 Jun 85) pp 240-247

[Article by V.A. Shklovskiy and Ye.I. Druinskiy, Kharkov Physical-Technical Institute, Ukrainian SSR Academy of Sciences]

[Abstract] The possibility of realizing explosive growth of the spherical front with arbitrary heat release and temperature of the medium is analyzed. The corresponding critical radius and pre-explosion heating time are calculated. The statement of the problem of non-isothermic growth of the spherical center of a phase transformation is examined in quasi-stationary approximation. The region in which explosive growth modes exist is determined. Quasistationary growth of the spherical center of a stable phase is found to be self-accelerating, and can occur explosively. The minimum heat release necessary to realize thermal explosion of the center is calculated. Figures 2, references 8: 7 Russian, 1 Western.

6900/12379
CSO: 1862/149

INTERFERENCE OF LIGHT WAVES WITH SUB-POISSON STATISTIC AND SENSITIVITY OF LASER GRAVITY OBSERVATION

Moscow ZHURNAL EKSPERIMENTALNOY I TEORETICHESKOY FIZIKI in Russian, Vol 90, No 6, Jun 86 (manuscript received 5 Oct 85) pp 1889-1899

[Article by M.I. Kolobov and I.V. Sokolov, Leningrad State University]

[Abstract] This study addresses the possibility of suppressing observation noise in interference experiments in which two light waves are mixed by means of an interferometer, semitransparent splitting plate, or other device, and one of the secondary waves is then sent to a photodetector with good quantum efficiency. The physical requirements for the spectral and temporal characteristics of the incident waves are explained, and the observation procedures under which natural fluctuations of the photodetector of secondary waves are suppressed are identified. A physical interpretation of quantum wave

phenomena is presented. The mixing of light beams by an interference device that is perturbed externally is of interest for laser gravity observation, as well as a method for controlling light that does not disturb the quantum statistics of the primary light waves. Figures 2, references 22: 12 Russian, 10 Western.

6900/12379
CSO: 1862/258

LIGHT-INDUCED CURRENT IN SODIUM VAPORS

Moscow ZHURNAL EKSPERIMENTALNOY I TEORETICHESKOY FIZIKI in Russian, Vol 90, No 6, Jun 86 (manuscript received 10 Nov 85) pp 1963-1971

[Article by S.N. Atutov, I.M. Yermolayev, and A.M. Shalagin, Institute of Automation and Electrometry, Siberian Department, USSR Academy of Sciences]

[Abstract] Light-induced current was investigated experimentally in sodium vapors, where no additional radiation is required for ionization because of the occurrence of associative ionization from the excited state. The occurrence of current in sodium vapors following the stated mechanism is examined theoretically considering the influence of optical pumping resulting from superfine splitting of the fundamental state. The antisymmetrical behavior of the current as a function of the detuning of the radiation frequency from the center of the absorption line of the gas is registered experimentally for the first time. The current value was investigated as a function of the resonant fluorescence intensity and the pressure of the buffer gas. The theoretical and experimental results were compared, showing good agreement. Light-induced current may become a method for intra-Doppler spectroscopy in the region of small currents thanks to slow ion accumulation. Figures 5, references 10: 9 Russian, 1 Western.

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CSO: 1862/258

LONG-TERM ACOUSTIC MEMORY IN POLYCRYSTALLINE MAGNETOSTRICTION FERRITE

Leningrad PISMA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 12, No 10, 26 May 86 (manuscript received 10 Feb 85) pp 599-603

[Article by M.V. Manuilov, V.S. Bondarenko, V.V. Krinochkin, and B.V. Sobolev]

[Abstract] Long-term storage of bulk acoustic waves in polycrystalline Ni-Co ferrite is investigated. The acoustic signal was recorded by applying a short electromagnetic pulse to a specimen in a demagnetized state after exciting a shift wave therein. Storage occurs when the frequencies of the initial wave and of the electromagnetic pulse applied are the same. This apparently results

in the formation of a regular structure of magnetic inhomogeneities due to slight shifting of the domain boundaries. When a second electromagnetic pulse is applied to the specimen, an acoustic wave is generated that is a copy of the initial one. The structure of the magnetic inhomogeneities formed is stable over time, apparently leading to an unlimited storage time. A static magnetic field with amplitude of approximately 100 E destroys this storage structure and allows another acoustic wave to be stored. The long storage time, high efficiency, short recording time, and possibility of erasing by using a small magnetic field create prospects for exploiting this phenomenon in devices for correlation processing of analog signals. Figures 3, references: 4 Russian.

6900/12379
CSO: 1862/252

PROSPECTS OF $Ln_{1-x}Sr_xCoO_3$(Ln:La, Ne) OXIDES FOR CATHODES OF CO_2 WAVEGUIDE LASERS

Leningrad PISMA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 12, No 10, 26 May 86 (manuscript received 26 Feb 86) pp 622-627

[Article by D.N. Zybin, N.I. Lipatov, P.P. Pashinin, A.N. Petrov, A.M. Prokhorov, and V.Yu. Yurov]

[Abstract] This study describe the results of a simulation experiment in which such electrical characteristics of $La_{0.7}Sr_{0.3}CoO_3$ and $Nb_{0.7}Sr_{0.3}CoO_3$ orthocobaltites with perovskite type structure as the normal cathode potential drop and the normal current density are obtained under the conditions of a typical CO_2 waveguide laser discharge. The findings are compared with the analogous parameters of such existing cathode materials as stainless steel, Ni, and TaC. Determining these electrical characteristics of the cathode material makes it possible to calculate the optimal geometry of the cathode assembly in advance for the corresponding laser and thus to ensure a normal molecular glow discharge for CO_2 waveguide lasers. Tables 1, figures 1, references 7: 3 Russian, 4 Western.

6900/12379
CSO: 1862/252

NONCONSERVATION OF P-PARITY IN MOSSBAUER TRANSITION OF ^{119}Sn NUCLEUS

Moscow PISMA V ZHURNAL EKSPERIMENTALNOY I TEORETICHESKOY FIZIKI in Russian Vol 43, No 11, 10 Jun 86 (manuscript received 28 Apr 86) pp 507-509

[Article by A.V. Baluev and V.I. Rogozev, Radium Institute imeni V.G. Khlopin, L.V. Inzhechik, Ye.V. Melnikov, A.S. Khlebnikov, V.G. Tsinoyev and V.M. Cherepanov, Institute of Atomic Energy imeni I.V. Kurchatov]

[Abstract] Nuclear spectroscopic methods have detected a large variety of P-nonparity effects related to the existence of weak nucleon-nucleon interactions, including asymmetry of quanta upon splitting of a polarized radioactive nucleus. This article measures a similar effect in the Mossbauer-M1 transition of the ^{119}Sn nucleus by means of nuclear gamma resonance spectroscopy. Asymmetry is observed in Mossbauer photons relative to the spin direction of the nucleus. The measure of P-nonparity is equal to twice the ratio of the adjusted matrix elements of the impurity E1 and regular M1 transitions: $0.94 \pm 0.08\ 10^{-3}$. Asymmetry is measured as a function of temperature, and no energy dependence of normalized asymmetry is observed. Figures 2, references 6: 5 Russian, 1 Western.

6508/12379
CSO: 1862/243

POSSIBLE NUMBER OF DIFFERENT KINDS OF NEUTRINO

Moscow PISMA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian Vol 43, No 10, 25 May 86 (manuscript received 21 Mar 86) pp 453-455

[Article by V.I. Manko and M.A. Markov, Institute of Physics imeni P.N. Lebedev, USSR Academy of Sciences]

[Abstract] The possibility of a relation between the number of neutrino kinds existing in nature and the dimensionality of space is examined, a hypothesis being developed about the physical meaning of the quantum number (lepton charge) as a description of neutrinos. The idea that not more than four or five kinds of neutrino can possibly exist in nature, based on astrophysical data and suggestive of a relation between this limit and the dimensionality of

space, is demonstrated on the model of a relativistic four-dimensional oscillator as an element of an array which forms a relativistic string and on a generalization of the Dirac equation which includes internal degrees of freedom. Lower-order excitation modes in such an oscillator are regarded as neutrinos and the equation for the Fourier component $\Psi(x^\mu,\xi^\mu)$ of the corresponding wave function is replaced with the equation for the bispinor $\Psi(k^\mu,\xi^\mu)$, with an additional relativistic constraint excluding vibrational states ("ghosts") on the time axis. On this basis there will be either one stable neutrino or three unstable ones. Exclusion of "ghosts" can also be stipulated in the form of an additional term in the Dirac equation with internal variables. This modified equation is shown not to have solutions corresponding to a spacelike energy-momentum vector k^μ, while a state with a timelike energy-momentum vector k^μ can be found upon transformation into the center-of-mass x^μ system of coordinates. On this basis there will be one stable neutrino and three or four unstable ones, with no transitions between them. References 5: 1 Russian, 4 Western.

2415/12379
CSO: 1862/222

UDC 533.951

LARGE-SCALE RESISTIVE INSTABILITIES OF RELATIVISTIC ELECTRON BEAM IN PLASMA CHANNEL

Tomsk IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: FIZIKA in Russian Vol 24, No 4, Apr 86 (manuscript received 17 Dec 84) pp 84-89

[Article by V.P. Grigoryev, A.V. Zakharov, and N.S. Shulayev, Scientific Research Institute of Nuclear Physics, Tomsk Polytechnic Institute imeni S.M. Kirov]

[Abstract] Transport of high-intensity relativistic electron beams through plasma channels is considered and long-wave low-frequency resistive instabilities of such a beam following collisions between electrons and other particles are analyzed, taking into account the nonlinearity of betatron oscillations as well as the variance of longitudinal electron momentum. The corresponding Vlasov equation of kinetics is solved by integration over trajectories. This method is applied first to an axisymmetric longitudinally homogeneous electron beam in the equilibrium state with charge neutralization. Its current is assumed to be partly compensated by the plasma current. Next is considered a beam with high electron concentration and high degree of current neutralization, carrying fast and slow waves. The results of calculations reveal a strong dependence of these instabilities on the degree of current neutralization of the electron energy variance and on the anharmonicity of betatron oscillations. One therefore can control them by changing the phase portrait of the relativistic electron beam at the entrance to the drift space and thus the radial profile of the beam current along with the radial profile

of the magnetic field of the net current. These conclusions have been confirmed experimentally. References 11: 7 Russian, 4 Western.

2415/12379
CSO: 1862/227

UDC 530.12:531.51

BOLTZMANN AND VLASOV'S KINETIC EQUATIONS IN ANISOTROPIC COSMOLOGICAL MODELS

Tomsk FIZIKA in Russian Vol 30, No 5, May 86 (manuscript received 4 Jun 84) pp 28-33

[Article by G.G. Ivanov, Kazan State University]

[Abstract] This study investigates the structure of the kinetic Boltzmann and Vlasov equations for spatially homogeneous cosmological models with allowance for Einstein's equations. Vlasov's collisionless equation for Bianci type II and Boltzmann's kinetic equation for Bianci type I are analyzed. The results obtained for various differential scattering cross-sections indicate that an ultrarelativistic collisional gas could be in a nonequilibrium state during early, strongly anisotropic, stages that is described asymptotically by a distribution function that is the exact solution of Vlasov's equation. References 4: 2 Russian, 2 Western.

6900/12379
CSO: 1862/250

UDC 530.12:531.51

GENERATION OF LONGITUDINAL PLASMA OSCILLATIONS BY GRAVITY PERTURBATIONS IN ISOTROPIC WORLD

Tomsk FIZIKA in Russian Vol 30, No 5, May 86 (manuscript received 19 Jun 84) pp 52-57

[Article by A.V. Zakharov, Kazan State University]

[Abstract] This study extends previous findings by the author that scalar gravity perturbations in an isotropic world are capable of exciting longitudinal electromagnetic fields in a plasma. The values of the electrical strength and density of the charge caused by scalar gravity perturbations in the lepton and radiation-dominated stages of expansion of the Universe are found. The formation of accumulations of matter is found to be accompanied in the radiation-dominated stage by the accumulation of a positive charge in the

central accumulation regions. The connection between the charge and the mass of the accumulations is analyzed. References: 3 Russian.

6900/12379
CSO: 1862/250

UDC 530.145

JOST FUNCTIONS FOR QUARK-ANTIQUARK SYSTEM

Tomsk FIZIKA in Russian Vol 30, No 5, May 86 (manuscript received 20 Jun 84) pp 57-60

[Article by S.S. Pikh and O.M. Lis, L'vov State University imeni I. Franko]

[Abstract] This study extends the generalization of the Jost function outside the energy surface of a system including more than two interacting particles to a quark-antiquark system interacting via the potential $V(r) = -\alpha/r+\beta r+V_0$. The Jost function outside the energy surface is found, as well as the T-matrix outside the energy surface and half within that surface. References 8: 1 Russian, 7 Western.

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CSO: 1862/250

UDC 539.23

EVOLUTION OF TEMPERATURE FIELD OF ABSORBER IRRADIATED BY STRONG ION BEAM

Tomsk FIZIKA in Russian Vol 30, No 5, May 86 (manuscript received 9 Jan 85 after revision) pp 89-92

[Article by V.I. Boyko, V.V. Yevstigneyev, N.N. Prilepskikh, and I.V. Shamanin, Tomsk Polytechnical Institute]

[Abstract] The fundamental principles of evolution of the temperature field of an absorber irradiated by a strong ion beam are investigated. A one-dimensional statement of the problem is employed because the ion energy in strong-current ion accelerators does not exceed several MeV/nucleon, and the ion free path in matter is much smaller than the transverse dimensions in a gas atmosphere or a vacuum is described assuming convective and radiant heat exchange on the barrier surface. The basic regularities of the temperature field evolution are investigated by irradiating an aluminum absorber with a strong proton beam as an example. The cooling parameters of the layers of the barrier are obtained numerically at various distances from the irradiated

surfaces. The surface layer of the absorber is observed to heat rapidly after the radiation pulse for substances that are good conductors of heat. Figures 2, references 10: 8 Russian, 2 Western.

6900/12379
CSO: 1862/250

COLLIMATION OF ATOMIC BEAMS BY LASER RADIATION PRESSURE

Moscow ZHURNAL EKSPERIMENTALNOY I TEORETICHESKOY FIZIKI in Russian Vol 90, No 3, 1986 (manuscript received 11 Jul 85) pp 871-880

[Article by V.I. Balykin, V.S. Letokhov, V.G. Minogin, Yu.V. Rozhdestvenskiy and A.I. Sidorov, Institute of Spectroscopy, USSR Academy of Sciences]

[Abstract] Detailed results are presented from studies of the collimation and decollimation of a thermal base of sodium atoms based on transverse cooling of the beam of atoms by the pressure of resonant laser radiation. Transverse cooling is found to cause a decrease in angular divergence of the atomic beam. The method of collimation studied in this work provides new capabilities for control of the velocities and coordinates of neutral atoms. Radiation collimation of beams allows elimination of the major obstacle to production of intensive streams of cold atoms--rapid spreading of atoms transverse to the axis of the atomic beam. The collimation effect, due to its frequency selectivity, may also be of interest for selective decreases in the angular divergence of beams of certain isotopes in systems for separation or detection of rate isotopes. Figures 8, references 11: 6 Russian, 5 Western.

6508/12379
CSO: 1862/198

LIGHT-ELECTRIC EFFECT IN SUPERCONDUCTORS

Moscow ZHURNAL EKSPERIMENTALNOY I TEORETICHESKOY FIZIKI in Russian Vol 90, No 3, 1986 (manuscript received 17 Jun 85; after revision 19 Oct 85) pp 993-1009

[Article by A.V. Zaitsev, Institute of Radio Electronics, USSR Academy of Sciences]

[Abstract] A study is made of the light-electric effect, which consists in the development of a steady potential and EMF under the influence of an electromagnetic field. In particular, the situation is studied in which a superconductor contains paramagnetic impurities. In contrast to the normal state, in the superconducting state, the excitation of EMF upon exposure to a

heterogeneous electromagnetic field involves redistribution of excitation among branches, while the change in the distribution function is insignificant. References 24: 15 Russian, 9 Western.

6508/12379
CSO: 1862/198

UDC 519.9

OPTIMUM STRATEGIES IN DIFFERENTIAL GAMES OF FIXED DURATION

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 286, No 2, Jan 86 (manuscript received 3 Jun 85) pp 284-287

[Article by Yu.S. Ledyayev, and Academician Ye.F. Mishchenko, Institute of Mathematics imeni V.A. Steklov, USSR Academy of Sciences, Moscow]

[Abstract] The known method of reducing a differential game of fixed duration to the extremum-search problem of finding the optimum strategy is applied to the motion of vector $x(t)$ in an n-dimensional Euclidean space R^n from its initial position $x(0) = x_0$. This motion is described by the equation $\dot{x} = f(x,u,v)$, where $f(x,u,v)$ is a continuous function of coordinate x and of control parameters u,v with values within respective compacts P,Q and one continuously differentiable with respect to x in $R^n XPXQ$. The set $f(x,P,v)$ is convex for any $x \in R^n$ and $v \in Q$, while the relation $|\langle x,f(x,u,v)\rangle| \leq \alpha(1+|x|^2)$ (α - constant, $\langle x,y\rangle$ - scalar product of vectors x and y, $|x| = \langle x,x\rangle^{1/2}$ - Euclidean norm of vector x) holds true for all $(x,u,v) \in R^n XPXQ$. A theorem is proved, with the aid of a lemma, pertaining to the optimum admissible strategy for the first player, with an exact lower bound in the set of all admissible strategies. For illustration, the conditions for optimality are applied to a linear differential game describable by the equation of dynamics $\dot{x} = Cx-u+v$ with a quality functional of the form $\sigma(\pi x)$ where $\sigma(x)$ is a continuously differentiable convex function and π is a constant matrix. References 9: 8 Russian, 1 ? (in Russian translation).
[132-2415]
/12379

UDC 519.676

OPTIMUM MONTE CARLO WEIGHTING METHODS

Moscow ZHURNAL VYCHISLITEL'NOY MATEMATIKI I MATEMATICHESKOY FIZIKI in Russian Vol 26, No 2, Feb 86 (manuscript received 6 Mar 84, after revision 7 Feb 85) pp 190-197

[Article by A.A. Zhiglyavskiy, Leningrad]

[Abstract] The problem of optimally selecting the distribution density of random elements in a sample, for a convex functional given in a set of nonnegative-definite matrices, is treated as a minimization problem. A class of optimality criteria in the theory of a planned experiment with linear regression models is considered, among them the most general one, for evaluation of integrals representing Fourier coefficients. The condition necessary and sufficient for satisfying such criteria and thus for existence and uniqueness of optimum distributions are established on the basis of a theorem provable with the aid of five lemmas. This condition must and can be generalized, on the basis of another theorem, so as to be applicable to not only differentiable optimally criteria but also nondifferentiable ones and, particularly, minimax criteria. The author thanks S.M. Yermakov for support and G.A. Mikhaylov for valuable comments as well as for the stimulus he has given by publishing the first nontrivial result ever obtained in this field. References 8: 5 Russian, 3 Western (1 in Russian translation).
[148-2415]
/12379

UDC 519.6:536.71

EFFICIENT ALGORITHMS FOR SIMULATION BY MONTE-CARLO METHOD OF EVENTS RELATING TO TRANSFER OF NEUTRONS OR GAMMA QUANTA

Moscow ZHURNAL VYCHISLITEL'NOY MATEMATIKI I MATEMATICHESKOY FIZIKI in Russian Vol 26, No 2, Feb 86 (manuscript received 18 Jun 84, after revision 18 Mar 85) pp 220-229

[Article by I.G. Dyadkin, Kalinin]

[Abstract] A set of four algorithms has been constructed for simulating, by the Monte Carlo method, the trajectories of neutrons or gamma quanta in problems of radiation transfer. Excess randomness of simulated trajectories arising upon transition from one medium to another, whether of different chemical composition or geometrical configuration, is eliminated by allowing for changes in input data. This decreases the variance of estimates. With $\omega_0 = (\omega_{0x}, \omega_{0y}, \omega_{0z})$ denoting an isotropically distributed three-dimensional vector, these four algorithms are designed to simulate a distribution density (ω_0-algorithm), neutron scattering symmetric at the center of mass and elastic ($EL\omega_0$-algorithm), Compton-effect scattering ($K\omega_0$-algorithm), and neutron scattering anisotropic at the center of mass (ELAN ω_0-algorithm). They are all validated by relevant theorems pertaining to distributions. With their correlation characteristics established and the correlation found to be even closer for gamma quanta, they have been programmed for a BESM-6 high-speed computer. Their efficiency in calculating the trajectory angles was tested, and only the ELANω_0-algorithm found to be less efficient than the corresponding conventional "two rotations" algorithm. References 10: all Russian.
[148-2415]
/12379

UDC 517.988.68:519.2

OPTIMUM AND QUASI-OPTIMUM REGULARIZING ALGORITHMS FOR SOLUTION OF STOCHASTIC INTEGRAL EQUATIONS OF CONVOLUTION KIND

Moscow ZHURNAL VYCHISLITEL'NOY MATEMATIKI I MATEMATICHESKOY FIZIKI in Russian Vol 26, No 1, Jan 86 (manuscript received 20 Apr 84) pp 23-24

[Article by M.V. Arefyeva, Moscow]

[Abstract] Solution of the convolution-kind stochastic integral equation $Ax = \int_{-\infty}^{+\infty} k(t-\tau)x(\tau)d\tau = y(t)$, $-\infty < t < +\infty$ with a deterministic kernel $k \in L_1(-\infty, +\infty)$ is considered, assuming that the right-hand side is given approximately as a sum $\tilde{y} = y + n$ with n denoting a "small" centered random noise of uniformly bounded spectral density. Such a stipulation is ill-conditioned according to Adamar, and solution of this equation as a problem of

filtration requires regularizing (smoothing) approximations. The problem then reduces to two problems: 1) constructing upper-bound estimates of the optimum error (accuracy) nonimprovable with respect to order of noise level and asymptotic as the noise level approaches zero; 2) constructing quasi-optimum approximations (efficient realizations) optimum in terms of Bayes' strategy and Wiener filtration. Solution to the first problem is obtained in the form of three existence theorems. Solution to the second problem is based on two theorems pertaining to necessary and sufficient conditions for optimality of Tikhonov regularizing algorithms with arbitrary regularizers in the class of even ones. References 11: 7 Russian, 4 Western (2 in Russian translation).
[123-2415]
/12379

UDC: 517.977

OPTIMIZATION OF LINEAR CONTROL SYSTEM BASED ON QUADRATIC TERMINAL QUALITY CRITERIA

Minsk DOKLADY AKADEMII NAUK BSSR in Russian Vol 30, No 1, Jan 86 (manuscript received 8 Jan 85) pp 17-20

[Article by M. Bibi, O.I. Kostyukova, Belorussian State University imeni V.I. Lenin; Institute of Mathematics, Belorussian Academy of Sciences]

[Abstract] A study is made of a problem in the class of piecewise constant controls $U(t)$, $\in T = [0,T_*]$. A condition is presented for optimality and an algorithm is constructed to achieve the condition. References 4: Russian.

6508/12379
CSO: 1862/112

UDC: 517.977.58

METHOD OF SOLVING ONE PROBLEM OF OPTIMIZATION OF SYSTEMS WITH DISTRIBUTED PARAMETERS

Minsk DOKLADY AKADEMII NAUK BSSR in Russian Vol 30, No 1, Jan 86 (manuscript received 25 Dec 84) pp 21-24

[Article by A.V. Borzenkov, Belorussian State University imeni V.I. Lenin]

[Abstract] An optimal control problem is analyzed in a system with distributed parameters. A theorem for the criterion of epsilon-optimality is presented and a method is suggested for solution of this problem based on the principle of successive reduction of the estimate of suboptimality. A numerical experiment was performed using a FORTRAN IV program run on a Ye.S.1033 computer. References 4: Russian.

6508/12379
CSO: 1862/112

UDC: 517.977

ALGORITHM FOR SOLVING ONE MAXIMIN PROBLEM OF OPTIMAL CONTROL

Minsk DOKLADY AKADEMII NAUK BSSR in Russian Vol 30, No 1, Jan 86 (manuscript received 9 Jan 85) pp 25-28

[Article by M. Ayden, Belorussian State University imeni V.I. Lenin]

[Abstract] A study is made of a problem in the class of piecewise constant controls $u(t)$, $t \in T = [0,T_*)$. An algorithm is constructed for solution of the problem in a continuous linear system. References 4: Russian.

6508/12379
CSO: 1862/112

UDC: 621.378.3

THEORY OF ROTATING LIGHT BEAM IN GENERATION OF A SUMMARY FREQUENCY

Minsk DOKLADY AKADEMII NAUK BSSR in Russian Vol 30, No 1, Jan 86 (manuscript received 15 Mar 85) pp 36-37

[Article by A.M. Goncharenko, Academician, Belorussian Academy of Sciences, and P.S. Shapovalov, Mogilev Division, Institute of Physics, Belorussian Academy of Sciences]

[Abstract] A study is made of a nonlinear crystal in which phase synchronism is possible upon interaction of two waves. It is assumed that generation of the summary frequency occurs in slightly diverging laser beams. Parabolic equations are presented to describe the generation ignoring the birefringence angle of the crystal. Light spot rotation parameters are determined. For the summary frequency beam resulting from the interaction of two elliptical gaussian beams, one of which rotates, the tangent of the doubled rotation angle of the spatial form and phase surface is K_3/K_1 times less than for a beam with frequency ω_1, indicating that the resultant beam rotates if one of the interacting beams rotates. If the initial beams rotate in opposite directions under certain conditions, the summary beam will not rotate.
References 4: Russian.

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CSO: 1862/112

UDC 519.8

ALGORITHM FOR FINDING THE OPTIMUM SOLUTION TO LINEAR MAXIMUM PROBLEMS WITH COUPLED VARIABLES

Minsk VESTSI AKADEMII NAVUK BSSR: SERYYA FIZIKA-MATEMATYCHNYKH NAVUK in Russian No 1, Jan 86 (manuscript received 22 Jun 84) pp 14-19

[Article by I. Azizov, Institute of Mathematics, BSSR Academy of Sciences]

[Abstract] Games with forbidden situations are considered, as optimum planning of a production with distribution of resources in a 2-level hierarchical system, where the problem is to calculate the optimum guaranteed result according to the optimum plan x* of the first player and plan y* of the second player. In an agreement between players, the first one is forbidden to select any x ($f_* \leq x \leq f^*$) for which $Y(x) = \emptyset$. The problem is formulated as a linear maximin problem and solved along with the corresponding problem of mathematical programming where the target function as well as all constraints are linear. The two problems are coupled, the x^0 component of the optimum plan in mathematical programming being the suboptimum plan of the first player in the game. An algorithm is proposed for solving the game problem, namely finding the suboptimum solution which will yield the suboptimum x^ε plan for the first player and the suboptimum y^ε plan for the second player. The algorithm, a finite one, is demonstrated on a numerical example. The author thanks R. Gabasov and Ye.I. Shilkin for interest and valuable comments.
References 4: all Russian.
[154/2415]
/12379

UDC 519.6:535

DIFFERENCE SCHEMES FOR CALCULATION OF PARAMETRIC INTERACTION OF OPTICAL WAVES IN NONLINEAR MEDIA

Minsk VESTSI AKADEMII NAVUK BSSR: SERYYA FIZIKA-MATEMATYCHNYKH NAVUK in Russian No 1, Jan 86 (manuscript received 29 May 84) pp 19-23

[Article by V.V. Drits, Institute of Mathematics, BSSR Academy of Sciences]

[Abstract] Solution of problems in nonlinear optics by the method of finite differences is considered, specifically of problems reducible to first-order

differential equations of the hyperbolic kind. The system of equations $\partial u_j/\partial t + A\partial u_j/\partial x = f(u_j, u_j^*)$, for instance, describes in the first approximation a broad class of problems in the theory of dispersion. Assuming that this system of equations with appropriate initial and boundary conditions has a unique solution with the necessary smoothness for approximating, a family of difference schemes is constructed for finding that solution. Since the right-hand sides admit polynomial buildup of slow complex amplitudes u_j of interacting waves (u_j^* - conjugate-complex amplitudes), the convergence and therefore accuracy of the schemes is estimated on the basis of a theorem with the aid of three lemmas. Only implicit difference schemes are considered here, usually constructed for solution of such problems as transient energy exchange between opposing waves or pulses, nonlinear three-wave interaction, or four-wave interaction in resonant media. References 9: all Russian.
[154-2415]
/12379

UDC 517.977.58

OPTIMALITY CRITERION IN MINIMAX PROBLEM OF OPTIMUM CONTROL

Minsk VESTSI AKADEMII NAVUK BSSR: SERYYA FIZIKA-MATEMATYCHNYKH NAVUK in Russian No 1, Jan 86 (manuscript received 18 Jun 84) pp 34-41

[Article by M. Ayden, Belorussian State University imeni V.I. Lenin, and B.R. Umarov, Institute of Mathematics, BSSR Academy of Sciences]

[Abstract] Control functions in the class of piecewise-constant functions are considered for the minimax problem of optimizing a dynamic system under given constraints. A reference control is introduced and assumed to be regular, any other one being reducible to a regular one by a special procedure. A suboptimality number is defined, to characterize the reference control and increases of the quality criterion obtained with the aid of the Cauchy formula. An optimality criterion is then introduced in the form of a relation sufficient and, in the case of a nondegenerate reference control, also necessary to satisfy. A nondegenerate reference control is defined in two ways, and the theorem is proved to be valid in each case. A second theorem establishes the condition sufficient for suboptimality of the reference control. The authors thank R. Gabasov and A.V. Guminskiy for formulating the problem and assisting in the analysis. References 3: all Russian.
[154-2415]

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